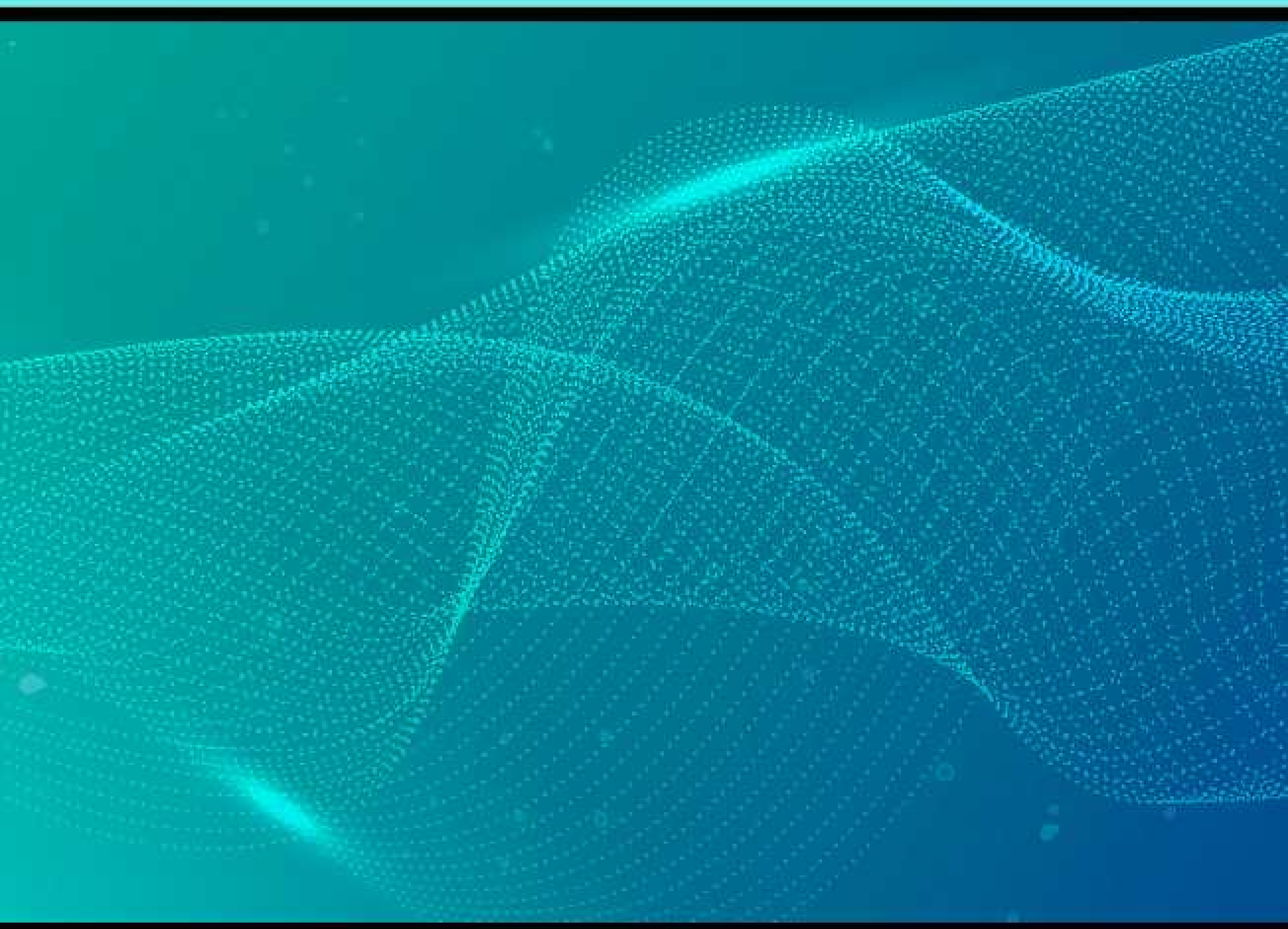
Power Industry Economics, Renewable Energy Systems, Electric Vehicles Engineering Design & Applications

Pravin Sankhwar



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India ▪ United Kingdom

BP International

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FIRST EDITION 2025

ISBN 978-93-49473-71-3 (Print)
ISBN 978-93-49473-70-6 (eBook)
DOI: https://doi.org/10.9734/bpi/mono/978-93-49473-71-3

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Peer-Review Policy: Advanced Open Peer Review policy has been followed for review. This book was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication.

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Contents

PREFACE

This book is a motivation from the author's contribution to the electrical power engineering industry from his professional work and research experience. The research studies and analysis presented in this book offer practical applications when it comes to the integration of renewable energy into the existing power grid. Being focused on the decarbonization of the power industry with electric vehicle charging stations powered from renewable sources such as wind and solar, the areas of focus in this book start with presenting solutions to how market forces can be turned in favor of an automobile, renewable energy, or any other industry.

The goal of this book is to present some research findings from the literature review and models for feasibility analysis of wind, solar, and combined systems for improving the penetration of electric vehicles. Practical challenges with electric vehicle charging stations for their power capacity became a driving force in the exploration of options for safe design and operation practices. The studies present innovative frameworks for both academic and working professionals.

Finally, the author is deeply grateful to the readers for taking the time to explore the book. The author is sincerely grateful to his colleagues, friends, and family for their valuable support. Especially my family, Niya, Nivaan, and Khushbu.

Print ISBN: 978-93-49473-71-3, eBook ISBN: 978-93-49473-70-6

Power Industry Economics, Renewable Energy Systems, Electric Vehicles Engineering Design & Applications

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Peer-Review History:
This book was reviewed by following the Advanced Open Peer Review policy. This book was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/4547

ABSTRACT

The power industry is enriched by the presence of diverse generations, from fossil fuels to renewable energy. Energy crises from the depletion of fossil fuels have been an area of concern during the planning of a sustainable future. Energy economics, by meeting the supply and demand changes, opportunity costs, and shifting industry from fossil fuels to renewable energy, becomes the basis of research. Fully electric vehicles (EVs) comprise an electric motor driven by a set of battery packs. Their adoption is increasing the extent of decarbonization of the transportation and energy sector. Studies have documented that EVs reduce emissions by a significant proportion when compared to conventional internal combustion engine (ICE) automobiles. Limitations from charging infrastructure and prospects of higher operating voltage and power capacities to modeling a battery circuit using a transfer function model became a decision maker in integration with renewable energy power generation resources from solar and wind. Wind and solar energy are available per India's wind speed and the solar map is the solution for increasing the renewable energy penetration into the power industry. Hydrogen production and storage to run fuel cell-based vehicles are feasible solutions per the MATLAB model and characteristics curves for the hydrogen output from the electrolyzer. Both fully electric vehicles and hydrogen-based fuel cell electric vehicles will decarbonize the market with reduced carbon emissions. The use of an integrated system of solar photovoltaics for generating hydrogen from an electrolyzer enhances the overall process and efficiency without depending on fossil fuels. The power industry benefits from engineering design in compliance with safety standards when implementing high-energy output charging stations. Additionally, major industry practices for the safe

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adoption of solar photovoltaics, wind turbines, electric vehicles, electric vehicle charging stations, hydrogen generation, hydrogen storage, and fuel cell-based electric vehicles become a motivator for this research work. For example, some jurisdictions across the globe have varying standards for the safety operability of electrical equipment where it is ensured that the users are exposed to limited electrical hazards without compromising the improved experience from shifting technology in the power and transportation industry.

Keywords: Power industry; economics; renewable energy systems; electric vehicles; engineering design.

1. DECISION INVOLVING OPPORTUNITY COSTS

The opportunity costs in the cost that the business must give up pursuing a different option that is more profitable to the company against its costs and benefits (Fagan, 2020). This is always a better idea to compare the costs/benefits and evaluate it against the opportunity cost (Fagan, 2020). The prime importance lies in the fact that the opportunity costs can be ignored sometimes and needs attention so that it is not unseen or ignored (Luke M. F. et al, 2018). The value associated with the opportunity cost is a determining factor in taking upon the decision (Fagan, 2020). In day to day lives we take decisions that have opportunity costs involved. For instance, buying a chicken sandwich for lunch or preparing a home-cooked meal has costs associated with health benefits. The chicken sandwich is expensive and less healthy than a home-cooked meal that is cheaper, fresh, and healthy. So, the opportunity costs it the costs forgone by not buying a chicken sandwich. However, the idea of purchasing home-cooked meals from local restaurants would have saved time for cooking and associated bills on gas consumption and dishwashing was ignored along with associated health benefits. Although, these costs are never shown in the company reports for the finances but often give an idea to the businessman how to increase profits during the decision-making process (Fagan, 2020). For instance, in past there were business decisions wherein the company had proposed to invest in the development of work through a different design software such as Revit (Pacheco, 2020). Although it needs more investment in hiring staff competent in handling the software, training sessions and license fees it has advantages in increasing profits by charging a higher fee for the design works (Pacheco, 2020). The costs need to be evaluated against the other option of software i.e., AutoCAD which is cheaper in terms of license fees and does not need a new recruitment or training as there is enough competence available within the company (Pacheco, 2020). However, the inherent drawback in not switching to an advanced version of design software to Revit is the company falls behind the new developments in the industry and loses to gain fees from clients ready to pay the premium price of these services (Pacheco, 2020). So, upon evaluation, it was feasible to switch software to Revit (Pacheco, 2020). However, the company should have also considered an option of using a mix of both AutoCAD and Revit as both are Auto Desk software and current staff would have adapted to the use of Revit easily by utilizing this option. This would have reduced the costs of hiring new staff and instead, a training session could have been purchased and provided to each existing staff member to go through thereby reducing the costs and increasing the benefits to both internal staff and customers.

The opportunity cost is calculated based on the below-mentioned formula (Fernando, 2020):

$$\text{Opportunity cost} = \text{Forgone Option's Return} - \text{Chosen Option's Return}$$

It is obvious that the opportunity cost must be positive to be able to make a wise decision in increasing the profits (Collamer, 2020). While working with the oil and

gas company for distribution of the products and services from a terminal facility several decisions have an impact on the operations and safety (Fagan, 2020). There was a time when due to refinery failure there was a shortage of petroleum products and the only way to meet the demands of the customers there needed to be decisions taken in either purchase it from other marketing companies or use the dead stock available in storage tanks but would have a safety concern if used (Ng & Beruvides, 2010). Purchasing the products from your competitors as a direct sales customer outside of contract adds costs and the company will end up paying a higher price than normal (Collamer, 2020). Upon evaluation of the costs of pursuing both opportunities, it was a good idea to purchase from other marketing companies and save the costs associated with safety forgone in using dead stock if pursued (Fernando, 2020). Also, the benefit obtained is the safety for the operations of the business in the operating facilities within the company which is foremost for any company to operate (Fagan, 2020). Again, the same concept of having a positive opportunity cost using the formula stated before helped in making the decision by the management and meeting the expectations and demand of the customers during the downtime of the operations of refining (Marglin, 1963). However, the option of utilizing the dead stock by taking the storage tanks out of service and handing them over to tank cleaning purposes would have saved costs for downtime needed for tank cleaning and same time use the dead stock for supplying it to the customers and would have significantly saved the costs and increased the benefits to the customers.

To sum up, opportunity cost in terms of selection of choices of options in increasing the profits and its benefit in the selection, the reason why options must be evaluated together with ensuring nothing is ignored were studied. The evaluation of two choices at various work assignments was presented with a comparison to the next available choice but expensive with fewer benefits must be forgone for good.

2. PRICING DECISION

The pricing decisions are made based on some of the concepts of marginal costs, marginal revenue, demand, supply, and elasticity of demand (Li, 2018). There are reasons why a company must redesign its pricing strategies on a time-to-time basis to remain dynamic to changes in the market and stay competitive against its core competitors (Luke et al., 2018). An excellent example of a pricing strategy followed by Ford Motors in lowering its prices which was a huge success is something people remember from the past (Koch, 2016). The company adopted a large-scale production at a low cost for offering the lowered price (Luke et al., 2018). During the 1920's the shares of Ford Motors rose to about three times as high as the closest competitor (General Motors) in the market (Koch, 2016). The major strategy followed was to slowly reduce the prices and gain market share followed by innovations to reduce the cost of production and gradually gain market share and beat the competitors (Koch, 2016). This is a success story and there are no shortcomings to list about the decisions taken by Henry Ford (Koch, 2016). However, let us consider the example of JC Penny and its pricing strategy (Sestek, 2021). Most retail companies work in pricing based

on promotional, psychological and a bit of fake pricing to drive sales (Sestek, 2021). For instance, if you were to buy clothes and the store offers a flat discount of 70% on $1000 shoes, you would go ahead and purchase it assuming you got a deal and saved $700 (Sestek, 2021). This has traditionally been followed and works well with people when they make purchases of clothes and merchandise (Sestek, 2021). However, the JC Penny tried to reduce discounts and vouchers on its merchandise and tried to reflect more accurate price tags which caught less customer attention and interest in buying as they did not get enough to rejoice in terms of savings by purchasing from JC Penny (Sestek, 2021). The feeling of saving $700 on a price-tagged item for $1000 no longer exists (Sestek, 2021). So, in my opinion, the company should have followed the traditional way of pricing the clothes high and then offered a discount (Sestek, 2021). Moreover, the basic idea of understanding the marginal cost vs marginal revenue generation analysis would have been performed to find at what marginal cost the company could generate the maximum profits (Li, 2018).

Let us consider an example of grocery store where the company owner decided to following pricing for the grocery item sold to the customers. With each additional quantity of the item, the price is reduced, and the profit figures are obtained. The product was priced at $10 for quantity of 10 items sold and maximum profits were generated equal to $23.5.

This decision was based on the analysis shown in Table 2.1 with values for MR and MC. However, the company could have adjusted the price as seen in Table 2.2 and had increased its profits. For instance, if you increase the price of the item by $1 each and with each subsequent increase in sales the price is reduced in a similar manner. The resultant profit in this case becomes $28.50 which is $3 higher than the previous case. Similarly, such pricing shall be adopted for the other grocery items too and the profits can be increased by the company. Moreover, the price can be reduced to a further low with a $2 drop for each increase in the quantity and the results can be obtained which could prove to increase the profits.

Table 2.1. Pricing strategy 1

Price	Quantity	Revenue	MR	MC	Profits
$14	1	$14	$14	$5.30	$8.70
$13	2	$26	$12	$5.30	$15.40
$12	3	$36	$10	$5.30	$20.10
$11	4	$44	$8	$5.30	$22.80
$10	**5**	**$50**	**$6**	**$5.30**	**$23.50**
$9	6	$54	$4	$5.30	$22.20
$8	7	$56	$2	$5.30	$18.90
$7	8	$56	$0	$5.30	$13.60
$6	9	$54	($2)	$5.30	$6.30
$5	10	$50	($4)	$5.30	($3.00)
$4	11	$44	($6)	$5.30	($14.30)
$3	12	$36	($8)	$5.30	($27.60)
$2	13	$26	($10)	$5.30	($42.90)

Table 2.2 Pricing strategy 2

Price	Quantity	Revenue	MR	MC	Profits
$15	1	$15	$15	$5.30	$9.70
$14	2	$28	$13	$5.30	$17.40
$13	3	$39	$11	$5.30	$23.10
$12	4	$48	$9	$5.30	$26.80
$11	**5**	**$55**	**$7**	**$5.30**	**$28.50**
$10	6	$60	$5	$5.30	$28.20
$9	7	$63	$3	$5.30	$25.90
$8	8	$64	$1	$5.30	$21.60
$7	9	$63	($1)	$5.30	$15.30
$6	10	$60	($3)	$5.30	$7.00
$5	11	$55	($5)	$5.30	($3.30)
$4	12	$48	($7)	$5.30	($15.60)
$3	13	$39	($9)	$5.30	($29.90)

To sum up, the pricing decisions taken by the companies based on the circumstances were discussed by including the success story of Ford Motors and the fall of JC Penny. However, the governing factors in pricing have many factors that need to be accounted but the concepts of MC and MR are dominant factors and can be incorporated into the pricing strategy followed by any company (Li, 2018). A comparison of the pricing followed for grocery store items was shared and the profit generation was shared with variations in the prices and increased quantity.

3. SPORTS SHOE COMPANY EXPANSION IN SPORTS BEVERAGES

Nike is one of the highly recognized brands for sports shoes and apparel. It mainly operates with manufacturing facilities in developing countries such as China and Vietnam to save costs (Nike., 2021). However, the largest factory for Nike is located in Memphis, TN and manufactures shoes, apparel and sports equipment (Nike., 2021). The facility itself is 2.8 M square feet and operates round the clock (Nike., 2021). There are strategies followed to reduce costs, greater services to the customers and have lesser service delivery time (Luke et al, 2018). This all is made possible with the availability of plenty of conveyor belts, outbound doors and receiving locations (Wood, 2016). Since the company has its brand image in sports shoes and apparel, it is a good choice for its manager to launch sports beverages under the same brand and utilize the well-established image to gain customer attention and increase sales (Wood, 2016). Moreover, there are greater chances of investors taking an interest in Nike’s new product line of sports beverages because of its successful history in the sports segment and loyal customers (Krake, 2005). When product costs are considered from the economies of the scope standpoint the existing facilities for manufacturing Nike’s products can be utilized for sports beverages (Pulley & Braunstein, 1992). For instance, the factories have the capability to receive and deliver the products to achieve the customer demand which can be used for new product lines (Brian & Euan, 2006). Additionally, the company can reuse the

existing staff, machinery, conveyor belts, electricity, and so on and just purchase additional equipment for beverage production (Wood, 2016). A pre-established network of vendors would help Nike spend less effort in terms of time and money (Brian & Euan, 2006). For instance, the vendors supplying technical support for software services such as ERP systems, automation systems and so on will be able to provide support for manufacturing processes involved in sports beverage production (Wood, 2016). In addition to that such vendors will provide discounts of additional support for reduced or no cost to the company as the services would essentially share the same platform used by the company (Pulley & Braunstein, 1992). Also, the supply chain network would be shared with the rest of the products (Pulley & Braunstein, 1992). For instance, the transport agencies and supplier network shall be utilized for the sports beverage distribution (Krake, 2005).

Usually, sports beverages are comprised of sugar, water, minerals, and elements such as potassium and sodium (Savage E., 2021). The purpose is essentially to get a quick boost of energy while bicycling, racing, hiking or any other sports (Savage E., 2021). However, there are newer additions to sports drinks with amino acids to reduce soreness in muscles, build up muscular strength and so on (Savage E., 2021). So, utilizing the brand image of Nike would create a psychological impact on purchasing the sports drink as the new customer will perceive benefits beyond its nutritional value (Pulley & Braunstein, 1992). The cost of the production of Nike would be low because of its proven technology and ability to add production by sharing costs on production with other product lines (Pulley & Braunstein, 1992). Essentially, the beverage industry requires water supply which is available in the manufacturing facilities already (Brian & Euan, 2006). Some of the raw materials can be repurposed or ordered in addition to meet the existing demand and the rest can be purchased (Wood, 2016). For instance, plastics and paper for bottle manufacturing can be purchased but packaging materials shall be repurposed or shared with other product lines (Brian & Euan, 2006). Moreover, there will be reduced costs in infrastructure addition for meeting power consumption, machinery, utility water supplies and so on (Brian & Euan, 2006). Thus, the company profits will be increased by utilizing the economies of the scope concept (Brian & Euan, 2006).

To sum up, the advantages of the launch of a new product line of sports beverages by Nike were enumerated. The processes involved in the manufacturing and supply chain network can be shared with the other existing products. This would reduce the overall cost and Nike would be able to take the cost advantage. However, some investments are required for the development of new product lines such as technology but with pre-established Nike vendors and investors, the likelihood of success rate is high. Moreover, customers would love to buy their favourite sports brand drink irrespective of any other value added. This would provide a head start amongst its core competitors and become successful (Krake, 2005).

4. CHANGE IN INDUSTRY DUE TO SUPPLY AND DEMAND CHANGES

The market conditions often change due to the entry of new competitors and the rise, and fall of demand and supply due to industry changes or customer behavior changes (Luke et al, 2018). There is a need to study the market and understand the industry trends to run a firm to improve profitability and be able to adapt to the changing market conditions (Rice University, 2021). There has been a shift in the demand for chicken due to customers' change in taste between the 80s to 2014, the chicken consumption increased while beef consumption fell indicating growth of fast food with chicken ingredients at higher sales than beef (Rice University, 2021). Moreover, the type of population of the people in the country changes the demand (Rice University, 2021). For instance, a high population of children in a country gives rise to the demand for bicycles, toys and so on (Rice University, 2021). Sometimes substitutes of the products reduce the demand for certain kinds of products and services (Changxiang et al, 2020). For instance, increased smartphone use reduces dependency on cameras (Brækkan, 2015). The high-quality camera offered with phones reduced customer interest and demand for separate camera devices (Brækkan, 2015). At the same time, several products can complement each other (Changxiang et al, 2020). A bottle of water may be complemented by soda as many people often drink either while they consume food (Rice University, 2021). The demand curve may shift based on the increase in the salary of the people in the area or region (Changxiang et al, 2020).

Table 4.1. Change in demand

Price ($)	Old Demand	New Demand
50	100	300
49	200	400
48	300	500
47	400	600
46	500	700
45	600	800

There are changes to supply as well which shifts as per the conditions (Rice University, 2021). The agricultural products in a particular geographical area would face a downfall due to conditions like floods or droughts (Rice University, 2021). There are several instances in India when due to flood conditions the cultivated rice and grains are spoilt and there is a shortage in the supplies in that geographical location only (Rice University, 2021). Moreover, some of the production facilities come up with breakthrough technology which reduces the costs, and they are able to increase the production to a greater extent and hence the supply curve shifts (Brækkan, 2015).

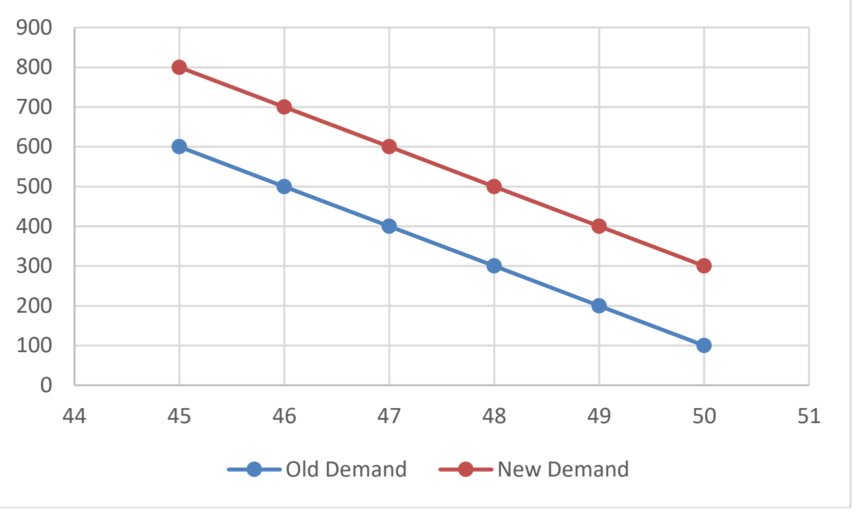

Fig. 4.1. Shift in demand

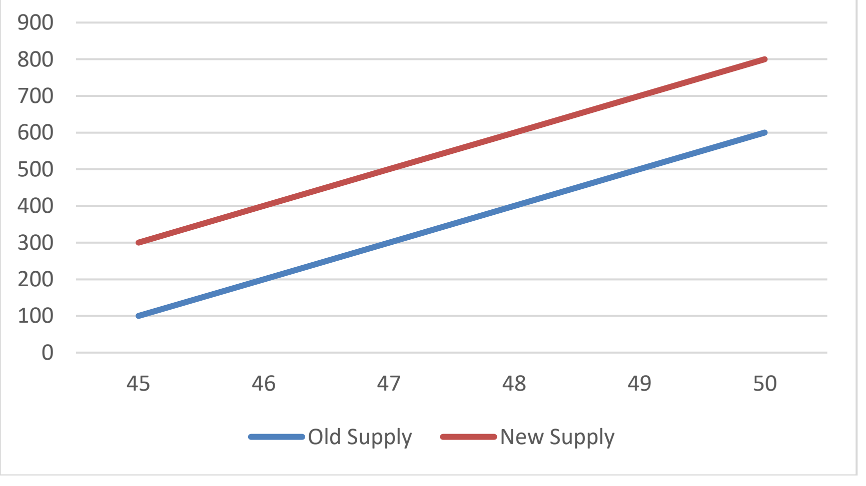

Fig. 4.2. Supply shift

Supply and demand must play a key role in the behavior of the rise and fall of the prices of the goods and services sold to the customer (Brækkan, 2015). A hypothetical, two-wheeler dealership selling automobiles in an area with no competition available within 30 miles of a driving radius gained benefits from the rise in the demand for two-wheelers due to many reasons such as the addition of roads to the rural areas close to the dealership (Rice University, 2021),

availability of financing opportunities from the banks sue to opening of new banks in the area, closure of nearest dealer in the area and so on (Changxiang et al, 2020). The firm can gain an advantage from the shift in the equilibrium point as seen in Fig. 4.3. The price point was Rs. 48,000 whereas with new demand it is Rs. 48200.

Table 4.2. Supply changes

Price ($)	Old Supply	New Supply
45	100	300
46	200	400
47	300	500
48	400	600
49	500	700
50	600	800

Table 4.3. Shift in market equilibrium

Price (Rs.)	Demand	Supply	New Demand
50,000	10	50	15
49,500	15	45	20
49,000	20	40	25
48,500	25	35	30
48,000	30	30	35
47,500	35	25	40
47,000	40	20	45
46,500	45	15	50
46,000	50	10	55

The profit implications of the change in the industry would be Rs. 200 per two-wheeler sold to the customer. For instance, if a quantity of 200 is sold in one month, then the total increase in profits is Rs. 40,000.

To sum up, the market changes were discussed with reasons for the shift in demand and supply curves with examples shared and demonstrated using graphs. There are several factors in the change in demand such as a rise in salary, change in customer behavior and so on (Changxiang et al, 2020). Similarly, the manufacturing facilities are able to increase the supply with the implementation of technology or have reduced supplies due to climatic conditions in that geography (Changxiang et al, 2020). For two-wheeler dealerships, the supply and demand change curves were presented and the shift in equilibrium was shown and the total profits earned out of making the changes were quantified (Changxiang et al, 2020).

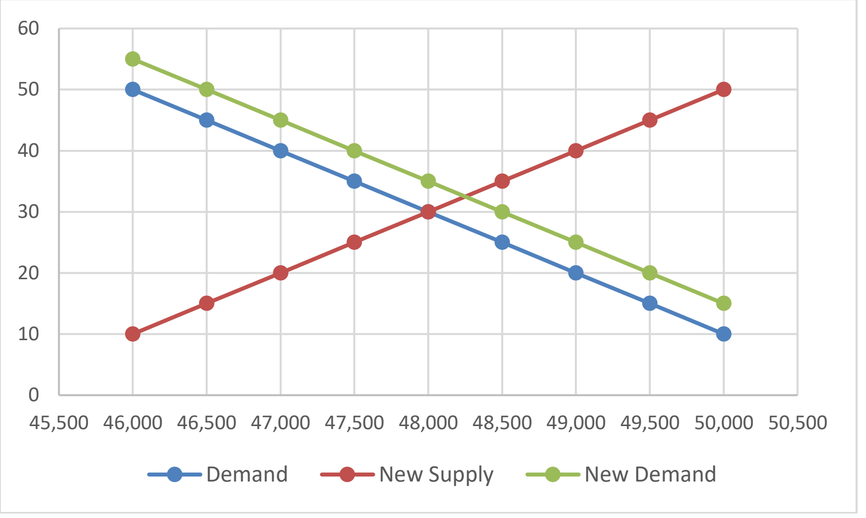

Fig. 4.3. Shift in the demand curve (X-axis: Quantity and Y-axis: Price)

5. MONOPOLY MARKET FROM BUSINESSMAN'S AND ECONOMIST'S PERSPECTIVE

A monopoly market is beneficial to the existing businessmen as they can take advantage of this opportunity to gain profits for a long duration until there is a new entry or new government regulation imposed which eventually erodes the market (Luke et al, 2018). For instance, the distribution of cooking gas in India is regulated by the government and there are no private players in competition with government-owned companies giving rise to a monopoly market (Posner, 1975). A change in government regulations would allow private companies to develop and obtain market share which would eventually affect the sales by government-owned business organizations (Yang et al, 2010). From an economist's perspective, there are several disadvantages of monopoly because of higher prices paid by customers for services, lesser availability of incentives in cutting down the costs and spending for innovations (Yang et al, 2010). There are also significant diseconomies of scale that persist which decreases the profitability to some extent (Yang et al, 2010). Due to inelasticity in demand created by the monopolistic market, the companies can increase the prices and customers must pay higher prices as they have no other choice (Posner, 1975). For instance, Microsoft can increase the price of its MS Office software because of its monopoly (Posner, 1975). The prices often tend to be higher than the MC (Yang et al, 2010). There are chances that the monopolies gain power from government policies (Yang et al, 2010). Some of the premium car manufacturers are able to increase the price of their cars because of a monopoly in the type of features offered which is difficult for them to find other than the brand. So, such

companies may be able to take undue advantages and take control of the prices (Yang et al, 2010).

But from a businessman's perspective, monopoly would be looked at as an advantage for them to grow businesses (Pettinger, 2020). The greater control over the types of good and services provided by one company have them dominate the market (Pettinger, 2020). For instance, a businessman would look for ways to gain greater control over prices in the market by following malpractices and influencing government decisions by using money and eventually trying to gain power (Pettinger, 2020). Also, businessmen would try to develop a new product line that is again a monopolistic market, all because of influencing government policies (Pettinger, 2020). Moreover, having enough control over prices for other businessmen may get challenging sometimes for their entry (Yang et al, 2010). There will be advantages taken in gaining from economies of scale by increasing production (Pettinger, 2020). Moreover, the businessman will be able to invest in R&D works to further increase the quality of goods and services (Yang et al, 2010). This is because they have a surplus of funds, are economically sound and able to invest in new infrastructure easily and will be able to hire the best talent in the market (Pettinger, 2020). The businessman will be able to offer the best salary and benefits to its employees (Pettinger, 2020). An example of a monopoly is a large retail store such as Walmart which was able to shut down all small-scale retailers by creating of monopoly (Yang et al, 2010). This is all because of their cheaper price offers because of the large distribution network worldwide (Pettinger, 2020). There will be no substitutes for the product in the market that is developed by a breakthrough technology (Pettinger, 2020). For instance, MS Office products by Microsoft had a monopoly back in a few years because of the non-availability of substitutes in the market for these services (Pettinger, 2020).

In conclusion, the advantages of a monopolistic market were compared for both the businessman and the economist (Posner, 1975). From an economist's perspective, it is observed that there are fewer advantages but greater disadvantages (Yang et al, 2010). For instance, there can be undue advantages taken by the companies and would hamper the growth of other related businesses (Posner, 1975). However, an established businessman monopoly would help the company prosper and stay on top of all the market players (Yang et al, 2010).

6. DRAWBACKS OF INCREASING THE VALUE OF PRODUCTS TO CUSTOMERS

Companies often focus on increasing the value of products to the customers to increase the profits for the organization (Luke et al, 2018). Product value is something that the customers are ready to pay for buying a product or a service, it gives an idea of what a customer would look for and what he would compromise or in other terms features that are sought in a product or service (Legenzova et al, 2017). Thus, a company should have an idea of the products that must be prioritized or features that need to be prioritized by the end

customers (Legenzova et al, 2017). For instance, if a mobile manufacturing company realizes that features such as camera quality are pressing for customers then they must manufacture models with superior-quality cameras and keep the end price the same by reducing other redundant features for the phones (Legenzova et al, 2017). However, there are certain drawbacks to increasing the value which increases the profits of the organization (Martins et al, 2020). The value may be increased but at the same time it is likely that the competitors would provide the same services or products at similar customer value this would result in a fall in prices because of the competition on the market of similar products and customers would be able to draw value at a lesser price which eventually would reduce the company profits (Legenzova et al, 2017). Thus, competition would be a limiting factor in this case and even though the company adopted a strategy to increase the value for instance providing superior quality leather bags with appealing color and texture, the result would be still eroding profits (Martins et al, 2020). On the other hand, if a premium brand is increasing the prices, then customers are still willing to pay for it and the company would increase its profits (Luke et al, 2018). The value of the product can be increased by cutting down the costs but there is no guarantee that the cost can be reduced (Martins et al, 2020). There is only a certain extent to wherein you can reduce the costs and further reduction is beyond control (Martins et al, 2020). Increasing value can be achieved by either marketing the product and creating a desire or need for services (Luke et al, 2018). For instance, advertising green tea and its health benefits would eventually increase the requirement and hunger from the customer end (Martins et al, 2020). However, the customer would only entertain a new product until a certain period and being new there are chances that in the short period of launch, the need for this new product is gone and no longer there would be any sales (Martins et al, 2020). On the contrary, the product may be successful and eventually develop business for the organization and they may be able to offer to the customers at a premium price (Martins et al, 2020).

The customer value can be broken down into three blocks namely profits, costs, and the surplus of the customers (Yu, 2021). If the value is fixed, then the only option is to reduce the costs. But when the value is increased by increasing the customer desires or needs then there is a possibility of increasing the profits, but it is possible that the costs rise in meeting the new value to the customer (Yu, 2021). For instance, the company plans on improving the value of the computer systems by improving the processor speed and upgrading it with newer processors, but this change would result in increased costs in getting the new processors (Milano, 2021). So, there is an overall increase in the value of the product supplied but the company faced an interim increase in costs may be due to new raw materials, shipment costs from vendors and so on (Milano, 2021). Also, there are chances that the rise in customers would be very low and may eventually fall due to which the company may not be able to sell enough of them to break even (Yu, 2021). This would hamper their long-run operations and bankruptcy (Martins et al, 2020). Moreover, the need for identification and how to increase the value may be misjudged by the marketing team and the company may invest in projects that are feasible as per the study submitted by the

marketing team but when implemented lead to failure in the achievement of desired sales and eventual drop and incur losses and reduced profits (Milano, 2021).

In conclusion, the customer value is often increased by the company to increase profits but there are chances that such value enhancement strategies will fail not only due to the customer's poor surplus but also due to failures in reducing the costs of new need-added or failure to identify the correct need that adds value (Yu, 2021).

7. SMART PHONE COMPANY AND ITS STRATEGIES IN BEING MARKET LEADER

There are several forces in the market in terms of the type of the product namely substitute or complementary nature that determine the course of action for pricing or strategies in the development of business in the market for any firm (Minglun et al, 2020). The same holds true when you consider Apple and its unique ways of becoming a pioneer in the market with products in Mac computers, iPads, iPhones and so on (Luke et al, 2018). During the early years of its incorporation, the Macintosh computer offered its unique features at cheap costs and a user-friendly interface for common man's use (History Computer, 2021). The company tried its best to come up with a product that is a market differentiator and made it difficult for its competitors such as IBM to build such computer products (History Computer, 2021). This is an approach wherein Apple wanted to gain a monopoly in the market with its products and services (History Computer, 2021). There were features such as a mouse and a graphical UI which was unique against the command prompt window features offered previously by other competitors (Minglun et al, 2020). The model itself has its hardware integration with software i.e. the Mac PC's run on its own hardware and software and other application software that are unique to itself (Shocker et al, 2004). It can build its own brand for all the software and hardware (History Computer, 2021). However, the application software is available on iPhone and is supported by Apple iOS phones because they want to stay competitive in the market by offering third-party apps installed so as to improve the user experience (Minglun et al, 2020). It is impossible for Apple to develop applications that suit the customers' needs (Minglun et al, 2020). People like various types of gaming, photography and so on (History Computer, 2021). For instance, the Facebook app is supported on iPhones and available on its app store for users to buy free. Such features encourage customers to buy Apple products as the users can't give up using Facebook (a social media platform) (Minglun et al, 2020). Thus, certain apps need to be supported on the iPhone to cater for a larger audience for Apple products (History Computer, 2021). This is a complementary products and services, as the apps are software and these increase the sales of iPhone and iPhone in turn increase the sales of the apps (Banton, 2020). This interdependency makes it a nice combination that would influence the decision of Apple Inc. to provide users with an opportunity to use the apps on the phones with their most liked applications (Banton, 2020). Such business models and practices are popular with other products and services as well (Shocker et al,

2004). For instance, there are baby packs available which comprise of a bundle of ointment, diapers, oil and so on (Minglun et al, 2020). All these products complement each other in one or the other ways (Minglun et al, 2020).

In contrast, the monopolistic approach in developing products for the customers and making it hard for the competitors to develop breakthrough technology to beat the existing product line for computers by Apple in its early years was an approach adopted to gain market share and become a pioneer with its unique hardware and software and improve the user experience with GUI and mouse features (Minglun et al, 2020). This led to its successful growth over a period and develop more products such as iPad, iPhone and so on (Minglun et al, 2020). However, there is no acquisition of the complementary applications by Apple in some cases (Banton, 2020). However, if it were applicable to most cases then the MR would have increased beyond MC and it would be advisable to decrease the prices of both products and services and increase the profits when pricing the products for customer use (Luke et al, 2018). However, Apple can have customers pay a premium price for its hardware and software- iOS, as these are not available from the market competitors (Luke et al, 2018).

In conclusion, there are strategies adopted by Apple Inc. to become the market leader by reducing the competition with offers in the Mac PC monopoly and later followed complementary products being supported on the iPhone such as applications (Facebook and so on) (History Computer, 2021). These approaches have led to its growth and development. Such practices while developing a business model with closely dependent products and services are worth learning as part of economics discussion (History Computer, 2021).

8. GAMING STRATEGIES OF ELECTRIC VEHICLE DEALERSHIP

There are several gaming strategies adopted by companies against companies that provide substitute products or complementary products (Luke et al, 2018). For instance, Coke and Pepsi are substitute products and in past, there have been numerous instances wherein Coke and Pepsi come up with advertisements to respond to each other to influence customer behavior (Kurichenko, 2020). There was an ad where Pepsi can wear a Coke Halloween costume to mock Coke whereas, Coke responded with a similar image and said Pepsi wants to become a hero by wearing its costume (Kurichenko, 2020). So, let us now study how the interaction of a Suzuki brand two-wheeler dealership and its interaction with the other brands of two-wheelers namely Honda, Bajaj and so on (Suzuki, 2021). Products such as Access 125 have its substitutes such as Activa (by Honda) and Chetak (Bajaj) (Suzuki, 2021). The dealerships have to publicize and reach out to the end customers with key market differentiators such as increased mileage (km/litres) and improved braking systems (Suzuki, 2021). However, there are complementary products such as the parts used as tyres, brake pads, mirrors, mechanic shops and so on (Suzuki, 2021). If spare parts manufacturing companies provide expensive products, then the profit margin reduces for the company as people would be discouraged to purchase the Suzuki branded two-wheelers (Suzuki, 2021). Moreover, if you look at the four-wheeler segment, both

Toyota and Suzuki planned to collaborate in manufacturing electric vehicles (Smith, 2019).

Table 8.1. Substitute products (assumed values/hypothetical)

Gaming Strategy (loss of revenue)	**Suzuki – Access 125**		
Bajaj - Chetak	**Moves**	**Accommodate**	**Fight**
(another competitor entry for	Move-In	+50K, +50K	100K,0K
Suzuki)	Move-Out	0,100K	-50K, -50K

The new entry of the dealership with a competitor product of Access 125 i.e. Chetak (by Bajaj) would either have both the dealerships gain INR 50K for each of them by accommodation from the Suzuki dealer to add Bajaj sales near to its sales area (Correia & Stoof, 2019). However, if it tries to fight then it is likely to gain if the competitor quits but if it stays then the overall loss is more because now the prices were reduced to beat the competition and there is a loss of revenue because of decreased sales and at the same time Bajaj dealership is losing because of it had to reduce the prices for entry and being competitive (Correia & Stoof, 2019). So, Nash equilibrium is obtained only when the new competitor is moved in (Bajaj Chetak) and accommodated by Suzuki – Access 125 sales by the dealership in the sales area of the existing Suzuki dealer (Charlers & Alvin, 2004).

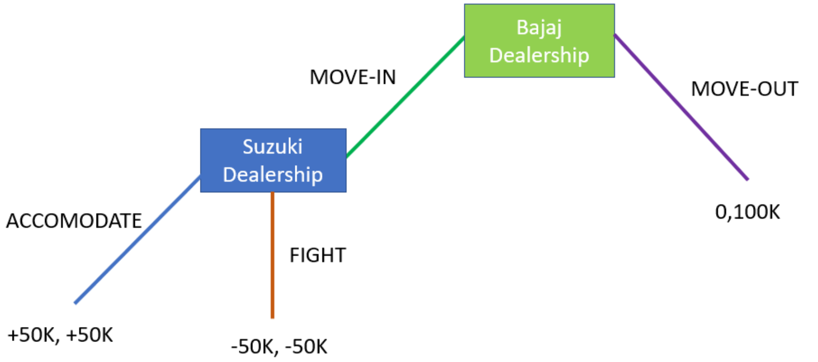

Fig. 8.1. Gaming strategies played by both dealerships (Luke et at, 2018)

If you can move out the new dealer by knowing their decision beforehand, this could be identified by knowing the financial situation of the new entrant for instance, if they don't have sufficient capital available for buying new land for dealership development then they are already out of the competition (Correia & Stoof, 2019). If this is known beforehand then the company can gain INR 100K irrespective of doing no work (accommodate or fight) (Luke et al, 2018). However, with nothing in the hands, if the other player enters and we fight, it's better to accommodate that case by keeping the prices the same for the vehicles

sold (Correia & Stoof, 2019). There can be other marketing strategies focussed on increasing customer delight and retaining existing customers by offering timely and quality services (Correia & Stoof, 2019).

In conclusion, the case study of the entry of a new competitor product which is a substitute was discussed and gaming strategies were compared for both the players and tabulated to identify the Nash equilibrium and there are possibilities of gaining the increased market share only when the other competitor moves out (which can be known or calculated by management's ability to envision) and company should not reduce the prices and lose any profits (Correia & Stoof, 2019). The quantification of the sales volume provided greater clarity in the sustenance of the business for an existing Suzuki dealership (Correia & Stoof, 2019).

9. MAKING DECISIONS WITH UNCERTAINTY

Decision-making without enough information on hand is very tricky and gets to a point wherein a strategy needs to be followed in terms of random variables associated with the decision and the probability of achieving the desired results for the same decision taken by the company (Luke et al, 2018). For instance, the probability of occurrence of heads or tails with a single toss of a coin is 50% each whereas the probability of scoring six with a single throw of dice is 1/6 (Lancer & Bourke, 2019). So, does the random variables evaluation for an event of decision-making yield different probabilities which must be understood while making a decision with no certainty (Sniazhko, 2019). The expected utility theory lists the order of occurrences of events based on the probability of its occurrence in order. This provides enough guidance to the management in making business decisions (Sniazhko, 2019). For instance, probability of getting approved by client A for projects is higher than client B then it is better to make the decision based on the probabilities (Sniazhko, 2019). It is like playing in a casino with known chances of occurrences of your favourable event (Sniazhko, 2019). Let us start a discussion of new product development X and Y, the comparison starts with how much it costs in the production of each product say $100 for X and $150 for Y. Then the discussion heads to how profitable is the product once out in the market. Say X would gain a profit of $30 per item sold and Y would gain $35 (Sniazhko, 2019). However, the total number of sales for X is expected to be 100 while for Y it is 200 (Lancer & Bourke, 2019). So, looking at the volume of sales and the probability that the expected sales align with expectations it is a good idea to pursue product Y (Sniazhko, 2019). Similar decision-making is done while making choices between two different prices such as price high or price low (Sniazhko, 2019). There are probabilities for either case to gain profits from high-value and low-value customers (Sniazhko, 2019). The greater profits from either segment with both pricing scenarios and probabilities would determine the decision. Sometimes the most obvious choice is the best decision made (Sniazhko, 2019). For instance, if you were going to purchase groceries then the closest store is the best choice keeping in mind it saves gasoline and the probability of getting a deal could be high within stores near your neighbourhood (assumption) (Lancer & Bourke, 2019).

Real estate is property which could include anything starting from water bodies, trees, buildings and so on (Chen, 2021). This is something which is stationary and different from personal properties such as boats, cars and so on (Chen, 2021). So, the term real property comes into the picture when we consider any new real estate business (Chen, 2021). Real estate is land plus the development above the land for the use of public or private use (Chen, 2021). There are several advantages to investing in real estate such as it provides secured income on a steady basis, but it is a non-liquefiable asset almost most times unless sold for and gotten rid of (Chen, 2021). For a friend who was to select investment in real estate, I would suggest looking at the historical interests and prices of the houses for investment in the real estate business (Chen, 2021). For instance, in the past 20 years, the prices of single-family units can be graphically shown and compared to times when the prices went down and the reasons for the same (Chen, 2021). There is limited control on interest rates due to market inflation or deflation but the factors affecting the economy can be classified and studied one at a time and probabilities of occurrence of rise or drop in prices can be studied for each factor (Chen, 2021). There are options for investment in real estate which is called mortgage-backed securities (Chen, 2021). However, it created a crisis in 2007-08 wherein the mortgage became the leading cause of the financial breakdown (Chen, 2021).

In conclusion, the need to understand the probabilities of the occurrence of the events is important when making decisions during the uncertainty involved (Lancer & Bourke, 2019). There are several theories that suggest the selection of the best option when making a decision but sometimes the most obvious choice is the best solution to the problem or decision taken (Lancer & Bourke, 2019). When investing the real estate, the need to understand the past trends based on the factors that affect the economy and the prices of the real estate shall be understood and evaluated by the person before even taking any risks in the investment business (Chen, 2021).

10. SHIFTS IN THE PETROLEUM INDUSTRY

The petroleum products marketing and refining companies that sell petrol, diesel, lubricant products, and their variants (TBP, 2017). This industry involves the refining of the crude received from vessels transported from rigs or through pipelines that run under the sea. Once the product is received, it is shipped to the refinery for the processes where petrol, diesel and lubricant variants are extracted by numerous processes (TBP, 2017). Then these are shipped using cross-country pipelines or by tank trucks and tank wagons to the terminals or depots from where it is dispatched to the dealerships (Hindustan Petroleum, 2021). This entire supply chain is governed by the operations and distribution department that employs the use of ERP systems in handling products and services (Hindustan Petroleum, 2021). Some of the major companies in this industry within India are Shell, Reliance Industries, Hindustan Petroleum, Bharat Petroleum, Indian Oil, Essar and so on (Roy, 2018). These companies almost have either downstream operations that include refining and marketing or upstream operations such as extraction of crude from the mother earth using

rigging operations (Roy, 2018). However, the reliance on oil and gas resources is shifting towards renewable energy in this sector so some of these companies are also delving into clean energy such as wind power or solar power (Olivera, 2007). But primarily these are focused on the energy sector consisting of oil and gas products and services delivered to the common man and industrial purposes (Olivera, 2007).

There are several ways the company (Hindustan Petroleum) has differentiated its services from the competitors such as providing superior quality by ensuring timely quality checks at each level of dispatch in the supply chain network, ensuring timely delivery of services to the customers by initiatives in training the front-line workers in handing customers, quantity assurance to the customers and so on (Hindustan Petroleum, 2021). The company offers a loyalty program to the fleet owners which provides an opportunity to individual and transport fleet truck owners to gain credits or points for every litre or gallon of purchase made (Hindustan Petroleum, 2021). This quality and quantity (Q&Q) assurance is in the mission statement and hence helps the management team to align their practices and ensure customer delight (Hindustan Petroleum, 2021). Moreover, the deployment of ERP systems in the accounting of products and indent management system for delivery and tracking of the products dispatched from terminals and depots to the dealerships (Hindustan Petroleum, 2021). The quality control labs ensure the collection of samples at various customer levels and perform testing of quality in terms of density, temperature, sulfur content and so on ensuring delighting customers (Olivera, 2007). Besides the company has launched campaigns for the Q&Q assurance and offering customers with payback points in a mobile application if they carried out testing activities at the dealerships (The Tribune, 2019). The greater intention of these activities is to cater for the attention of the general public and aware them with keeping their continued commitment to the products and services offered by HP dealerships (The Tribune, 2019).

Over the next five years, there will be several factors that will affect the value created for the common people (The Tribune, 2019). Due to the rising energy crisis developing with a fall in oil and gas reserves globally, energy consumption is transitioning towards clean energy (Abdi, 2018). Electric cars, solar farms, wind power and so on are becoming popular and widely accepted across the world (Olivera, 2007). So eventually due to the transiting of primary fuel of consumption by customers i.e. petrol and diesel, the customers will be more involved in buying cars that could rely on both types of fuel (Abdi, 2018). Thus, the value of the products such as petrol, diesel and so on will be enhanced by offering low-carbon emitting variants. Additionally, there could be a chance that some residual contents of refining would be useful for meeting the future energy demand such as natural gas (Abdi, 2018). So, the value could be increased by using natural gas as a major fuel supply for meeting domestic customers and industrial customers' demands (Olivera, 2007). Moreover, diversification into renewable energy which is already happening in this sector would increase the value of the energy supplied to the end customers (Olivera, 2007). Although, it is inevitable to see a change in customer behavior in terms of energy consumption

and use in a few years from now there will still be improvement in the value added to the customer for the products supplied by this industry such as petrol and diesel (BASF, 2021). Diesel has already been anticipated to be substituted by petrol and battery power in future (BASF, 2021). But it looks like there will be value added to diesel customers such as farmers, industrial customers and so on through petrol or battery systems (BASF, 2021). There is also likely hood of reinventing the business model and being prepared for the uncertainty in the future of energy use (Ashraf et al, 2020).

11. IMPORTANCE OF ACTIVITY-BASED COSTING IN MANUFACTURING FACILITIES

Abstract:

The managers must take care of the internal decision by proper use of the accounting figures available in the internal environment. Especially in a large manufacturing unit with low and high-volume products and services delivered the accounting of the overhead costs incurred needs to be allocated so that an optimal pricing decision is made. Traditional costing allows undifferentiated allocation of the overheads to all types of products irrespective of the volume. However, the activity-based costing had a greater significance when a literature review was performed to study the advantages of ABC and its success. Later on, a comparison of two hypothetical products “X” and “Y” distinguished based on the volume was performed against following the traditional methodology and activity-based methodology to understand how it would impact the pricing strategy being followed. The steps followed in the ABC were enumerated and presented in a manner to be able to be understood by a person with a non-business background. A general analysis has provided insight into the application of ABC for the management in making the right decisions for the betterment of the company.

11.1 Overview

The activity-based costing is applicable to manufacturing facility businesses which require the most reliable data for the costs including the true costs borne by the entire process of production within the industry (Brenner, 2020). This guides the management accountants in helping the decision-making processes in pricing the products and services (Kenton, 2020). In this methodology, the costs related to the overhead and the indirect headers are applied to the services and the offered products by the company (Chenhall, & David, 2011). The entire purpose of managerial accounting is to include all the accounting figures related to the internal operations of the company for evaluation purposes for the management staff in the decision-making process (Brenner, 2020). Hence, for a manufacturing industry, the key areas of the focus for the accountants include raw materials costs, production costs, labor and wages costs, repair, and maintenance costs and so on (Strover, 2020). The raw material includes the inflow and outflow of the materials from the facility (Chenhall, & David, 2011). For instance, for the cement industry, the inflow includes sand and gravel, coal,

gypsum and so on (Chenhall, & David, 2011). The outflow includes the fly ash and other waste materials to be treated for recycling. Production costs include electrical energy consumption, bills, machinery, technology and so on (Strover, 2020). The labor and wages are standard wages paid to the staff and the shift operators and so on (Chenhall, & David, 2011). Additionally, the maintenance and repair of the equipment has another cost component (Brenner, 2020).

11.2 Purpose of Research

The purpose of the research is to identify the optimal use of the ABC and devise proper tools in the calculation of the costs to have an accounting done in a fashion that provides more accurate results for the development of a pricing strategy for the company management (Kenton, 2020). Firstly, all the activities related the production are identified and tabulated in an orderly fashion (Kenton, 2020). Secondly, all the activities are categorized into various pools of cost which is then overhead for each header is obtained (Kenton, 2020). Thirdly, the assignment of the activities with respect to the pools or headers of costs is done based on the hours/ units (Kenton, 2020). Fourthly, the overheads are divided by the total costs of each driver for each header or the pool (Kenton, 2020). Finally, the rate for the cost driver is obtained and then multiplied by the total number of the drivers of the cost (Kenton, 2020). There are advantages to the adoption of this strategy allows the overhead to be included in the wide range of pools (Kenton, 2020). Moreover, the activity-based allocation ensures activities have been accounted for rather than volume measures adopted traditionally (Brenner, 2020). This ensures the overhead are accounted to low volume services or products from the high-volume ones (Kenton, 2020). The basis of the accounting utilized the variance analysis and activity-based costing for identification of the production activities involved (Brenner, 2020). So, the objective of the overhead, labor costs and the costs of raw materials to be accounted for in optimizing the operations for application in the use of correct manpower, reduction of the waste products and the indirect cost accounting is achieved using the ABC (Brenner, 2020).

11.3 Review of Literature

Kaplan (1988) presented the traditional methods adopted in costing which helped with pricing and mentioned some of the drawbacks which limit the proper accounting of the overhead costs and hence decision-making processes (Cooper & Kaplan, 1988). However, Knezevic and Mizdrakovic (2010) present the difference between the traditional methods and ABC. Traditional methods have more cost drives based on the volume basis and overhead costs are included with products and services (Knežević & Mizdraković, 2010). The research highlights the limitations in terms of the requirement for more labor/machine work hours when costs are assigned to the products and the services (Knežević & Mizdraković, 2010). However, with the ABC accounts the indirect costs properly to the production. There were examples quoted for the type of activities such as cleaning and disinfection of the kitchen after food production is done for a food processing industry just to understand the types of the activities. So, there was a

definition of “activity” presented here which states that it is an action that is repeated and moves the operations in an orderly manner (Johnson & Kaplan 2007).

Moreover, the difference in the number of stages with the traditional approach is four whereas with activity it is just two which simplifies a bit (Effiong & Eakpan, 2019). Phase one comprises the allocating of the costs by determination of the indirect costs at a whole entity level of the industry (Effiong & Eakpan, 2019). The other phase is essentially the definition of the activity as discussed earlier and evaluating the overhead costs with respect to the same (Effiong & Eakpan, 2019). Work presented by some experts such as Johnson and Kaplan (2007) has consistently highlighted the shortcomings of the classical approach. Effiong and Akpan (2018) present effects on productivity when talking about activity-based pricing (Chenhall, & David, 2011). How effectively the activity-based costing improved the production efficiency was evaluated with respect to the fitness of the cost drivers, creditability of the information on the cost, accuracy and precision of cost calculations and usefulness of the reporting followed for the costs (Effiong & Eakpan, 2019).

11.4 Practical Application

The concept of the ABC can be applied to practical application to the two products (X and Y) that are being manufactured at one company facility (Chenhall, & David, 2011). Say product “X” which is a small-volume commodity and will need some technology, analysis with testing activities and machinery for production (Chenhall, & David, 2011). This can be compared to a much similar product “Y” which is essentially a running and has greater volumes and moves through the flow line smoothly (Chenhall, & David, 2011). The company would adopt a traditional approach the overhead would be all the machine working hours evenly allocated (Chenhall, & David, 2011). The product “Y” will have a huge amount of machine hours and thus the overhead as compared to “X” since it has lower hours related to machine operations being a low volume (Chenhall, & David, 2011). So, essentially if the overhead is distributed to all the activities such as technology implementation, new machinery application or testing-related works then the cost would be evenly distributed to both products “X” and “Y” based on the activity assigned (Chenhall, & David, 2011).

The formula of obtaining the ABC is mentioned below (Stover, 2020):

$$ABC = \frac{Total\ cost\ of\ the\ Pool}{Driver\ realted\ to\ the\ cost}$$

And allocation of the overheads is given by (Stover, 2020):

$$Overhead\ Allocated = (Activites\ Number)(Per\ Activity\ Cost)$$

11.5 Conclusion

The shortcomings of the traditional methodology in cost allocation were discussed for the manufacturing industry and the need for activity-based costing in improvement of the allocation of the costs was discussed with respect to accounting management. There is a significant improvement in defining the activities and then allocating the costs for the low vs high-volume products and services. The formulas presented in this study were helpful in greater understanding to the readers in the calculation of the activity-based costing for products "X" and "Y" and allocating the overheads to each activity for preparation of the accounting entries. Moreover, the advantages presented with this study for an activity-based approach in simplification of the stages just limited to two rather than four adopted in the traditional approach is presented and discussed using the literature review available.

12. STANDARD COSTING, VARIANCE ANALYSIS AND DECISION MAKING

Abstract:

Standard costing is a technique that is more modern for accounting purposes of the costs and has a greater depth for the management in decision-making processes. The variance calculations by comparing the actual vs the standard costs are helpful in the streaming of the betterment of the manufacturing or the production of the goods and services. There is enough evidence available from the literature review that the resources can be utilized effectively by use of this costing method. Moreover, greater control of the budget is possible with this approach along with simplification of the decision-making process. However, advantages outweigh the shortcomings such as demotivation of the worker staff for no difference between poor and good performance. A practical application of studying the variances related to both direct materials and direct labor was presented for the manufacturing of table wooden material of dimensions 2 feet x 1 feet. The variances were tabulated, and the results were studied for the necessary decision-making process by the management staff.

12.1 Overview

There are several advantages to standard costing such as the control of cost improvements, useful data for proper decision-making processes for planning, better tools in measuring inventory available, saving costs for maintenance of records and reduced costs in production (Luke et al, 2018). The costs incurred by each type with variances included provide improvement in cost control for the firms (Berger, 2011). An evaluation of the variances helps understand whether the materials were utilized efficiently or not and resulted in increased prices (Walter, 2021). There are greater chances of the development of standards in costing and success with control of the costs incurred in production (Shattarat & Shattarat, 2021). Moreover, some assumptions such as the cost of each unit

produced during the same time frame ideally having the exact same price are part of the standard costing (Berger, 2011). However, there are a few disadvantages of standard costing such as some unreasonable variances that are acceptable to higher management as part of standard costing which might demoralize the worker staff who will see it as an improper low performance being ranked same as higher performance (Walter, 2021).

There are also possibilities in some of the variances that are not reported by the working staff which would eventually affect the effectiveness of the allocations budget (Berger, 2011). The variance analysis helps with the comparison of the planned vs the actual figures for the costs (Shattarat & Shattarat, 2021). This is a good way by which the performance can be evaluated if it is under or above the desired benchmark (Walter, 2021). The managerial staff can see the ones that are quite out of the way variances and look for improvements (Berger, 2011). This provides an opportunity to not only identify and fix the problems but also to seek options for improvement of the performance of the companies (Walter, 2021). Standard costing is advisable for bigger companies or firms as they have a greater quantity of products and services provided with manufacturing facilities and a greater amount of resources available for all the production processes involved (Berger, 2011). However, smaller-sized firms may be able to take advantage of other methods such as activity-based costing and so on (Shattarat & Shattarat, 2021). Healthcare Organizations have taken advantage of the standard costing and there are observed high levels of variances in the costs incurred in this sector (Berger, 2011).

The variances reported are often evaluated by the management staff for decision-making processes (Walter, 2021). The actual costs are not equal to the standard costs and hence a total variance is calculated by adding the price variance and the quantity variances together (Berger, 2011). The price variance for the materials is obtained by subtracting the stand price and actual price and multiplying with the standard price (Fałat, 2019). The quantity variance is obtained by subtracting the standard quantity and actual quantity and multiplying with the standard price (Shattarat & Shattarat, 2021). The variance for direct labor is calculated by obtaining rate variance and efficiency variances separately and adding it together (Berger, 2011). The rate variance is the difference between the standard rate and the actual rate multiplied by actual hours (Walter, 2021). The efficiency variance is the difference between standard hours and actual hours multiplied by the standard rate (Shattarat & Shattarat, 2021). This can be seen in Fig. 12.1 (Catalano et al, 2020). The delta here highlights the interconnection with the variances calculated for price, quantity and hence the overall variance (Shattarat & Shattarat, 2021).

These variances are finally entered as journal entries to record all the variances found (Fałat, 2019). Such entries would include reporting price and quantity variances in reducing income levels during unfavourable cases and rising income levels with favourable cases (Walter, 2021).

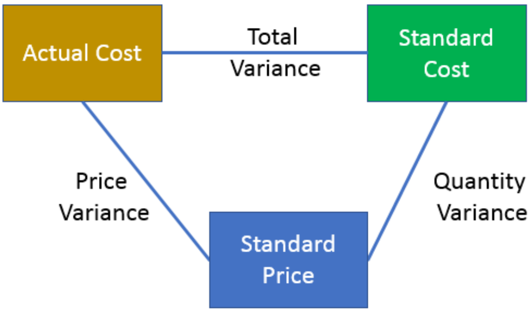

Fig. 12.1. Interrelationship (Walter, 2021)

12.2 Purpose of Research

The purpose of the research is to understand the importance of standard costing and variance analysis for decision-making by the company (Shattarat & Shattarat, 2021). Standard costing when implemented by comparing the expected cost with the actual ones results in proper accounting for decision-making in larger production facilities (Catalano et al, 2020). Through literature review, the major advantages will be understood and the variances for a hypothetical production of tabletop/heads will be discussed (Catalano et al, 2020). Such variances in the direct materials and direct labor would help get an idea of the need for improvement areas for the production facility (Catalano et al, 2020). In case the company expenditure is more than the expected costs on the materials used, overhead for the manufacturing and labor then there need to be decisions made for improvement (Catalano et al, 2020). This could be starting by reducing waste material, optimal manpower utilization and so on. In this study there is quantification done for the standard costs, actual costs and the variances related to direct labor and direct materials (Catalano et al, 2020).

12.3 Literature Review

Peskir & Pedersen (2016) have posited a function and mathematical analysis for maximizing or minimizing the variances obtained (Peskir & Pedersen, 2016). Such techniques can be helpful while analysing company managers for decision-making processes (Peskir & Pedersen, 2016). Lee, Lan and Tsai (2020) have presented the breakup of direct labor cost into fixed labor, electricity power, machine cost and the emissions cost for manufacturing the goods for application in ABC but the break-up is useful in studying the direct labor cost for standard costing (Lee et al., 2020). Silvester (2017) has presented Excel tools in the study of the standard costing and variance analysis step by step for learning of students, this adds value to the management of the companies in performing this analysis and understand the steps involved and analyse them for decision-making processes (Silvester, 2017). A case study presented in this paper enumerates the actual and the standard costs in Excel format by each header (Silvester, 2017). Falat (2019) introduces the importance of changes in the

information technology systems when there is a change in the costing strategy of the product (Fałat, 2019). This study also lists the results of the variances for finished goods for normal vs standard costing (Fałat, 2019). Thus, an idea of how a changing costing would affect the accounting is presented and would be of value to the managers using these tools and techniques (Fałat, 2019). Standard costing has been used to define some of the future elements used in the costing which has more accuracy than the traditional methods of costing in managerial accounting. Shhatarat & Shhatarat showed the importance of the implementation of modern techniques presented here for the costing methods which is in line with what Falat has posited in the research paper (Fałat, 2019). They have also mentioned that there is evidence that companies that implemented standard costing have performance boosts (Shhatarat & Shhatarat, 2021). Also, the two types of costing strategies have been compared namely activity-based costing and standard costing by the implementation of the lean principles for manufacturing (Shhatarat & Shhatarat, 2021). This study highly relied on the information collected from the survey (Shhatarat & Shhatarat, 2021). The study does recommend the need of implementation of future costing methods for better results (Shhatarat & Shhatarat, 2021). The linear regression analysis was used as part of this study and the relationship between the standard costing and the performance of the industries was studied for Jordan (Shhatarat & Shhatarat, 2021).

12.4 Practical Application

The practical application of standard costing can be understood by considering an example of standard material cost comparison with the actual material cost for a section of wooden frames cut for table manufacturing (Walter, 2021). The standard size available is 2 feet x 2 feet but the required is 2 feet x 1.5 feet, which leaves an unused plank of 0.5 feet x 2 feet left unused (Walter, 2021). The standard material cost can be evaluated as below (Walter, 2021):

Table 12.1. Standard material cost

Std. Quantity	500 pieces
Std. Price for each unit of wooden planks	$100
Total Std. Costs (Direct Materials)	$50,000

However, the actual material cost would be for expenses for the material wasted as well and can be tabulated for the actual consumption of the direct material for the manufacturing of the tables (Walter, 2021):

Table 12.2. Actual material cost

Actual Quantity	550 pieces
Actual Price for each unit of wooden planks	$110
Total Actual Costs (Direct Materials)	$60,500

Thus, the total price variance is ($100 - $110) x 550 = ($5500) and the material variance would be (550-500) x 100 = $5000.

The standard labor cost can be tabulated as below (Walter, 2021):

Table 12.3. Standard labor cost

Std. Hours	500 x 2
Std. labor rate	$10
Total Std. direct labor	$10,000

The actual labor cost can be tabulated as in Table 12.4 which lists out the actual hours of the labor and then the standard direct labor total (Walter, 2021):

Table 12.4. Actual labor cost

Actual Hours	1100
Std. labor rate	$11
Total Std. direct labor	$12,100

The labor rate variance shall be obtained as ($11 - $10) x 1100 = $1100. Moreover, the labor efficiency shall be obtained as ($1000 - $1100) x $10 = ($1000). The price variance can be reduced by the reuse of the wasted material (Fałat, 2019). This material could either be sold and obtain scrap value or the table size itself shall be modified to take greater advantage of the use of the whole material piece available (Walter, 2021). Thus, the translation of the variances by the management is key to the improvement of the utilization of the material resources for the manufacturing of tables in this scenario (Avercamp, 2020).

12.5 Conclusion

The advantages and disadvantages of standard costing were enumerated as part of the studies presented here in this paper. Although, the application of standard costing is applicable to larger firms in general but has advantages in the decision-making process by identifying areas of improvement in the variances calculated. There is evidence available that the standard costing does help with the improvement of the performance of the companies. Moreover, the results presented for a hypothetical case of tabletop production provided insight into how to obtain the variances and account for these in journal entries for the managers to take a look at and make decisions in increasing the performance of the company whether it is related to the direct materials used, repurpose or take advantage from scrap sale or to improve with respect to direct labor costs by optimal use of the manpower for the production of the goods and services (Fałat, 2019).

13. BASICS OF PROJECT MANAGEMENT

13.1 Introduction

Have you worked on a project before? The answer lies in the definition of the project. The projects are transitory and have a predetermined objective achieved by following a planned process to achieve the required results. Cooking a meal is an excellent example wherein the objective is to prepare a tasty and appetizing meal. The objectives are to prepare a tasty and appetizing meal, and the recipe becomes the process. The Project Management Institute (PMI) defines the project as “a temporary endeavor undertaken to create a unique product, service, or result”. The understanding of the project being transitory and having a definite end drives the project teams to accomplish within the given timeframe. For example, meals cooked at restaurants require preparation to be able to deliver the food within a given timeframe since the customer placed the order. Untimely delivery of the food service results in unhappy and dissatisfied customers. Knowing the objectives of a perfect food service helps the food servers, chefs, and other staff prepare the meal as per the customer’s expectation each time.

Objective → Processes → Results

13.2 Project Management

Project Management is an art and not necessarily limited to the management of the project but also to develop a sustainable model for future projects. For example, satisfied key stakeholders and customers may result in future projects being assigned to the same project teams or business. PMI defines project management as “the practice of using skills and techniques to complete a series of tasks”. In the food service industry, the manager employs their skills, knowledge, and experience in the successful delivery of the task.

Define Objectives → Follow Processes → Ensure Quality & Timelines → Results

Were you satisfied with your meal purchase yesterday? Do you consider yourself a stakeholder for the restaurant? A project manager understands the need for feedback from customers and values them as they are key stakeholders. Although this project seems like a routine task, it fits within the definition of project management when objectives are defined for sales during a given period.
Effective project management skills include excellent communication, customer service, motivation, leadership, and active listening. Many might feel project management is driven by following pre-defined steps, but truly, it is an art. The creativeness comes from the fact that the project has a defined objective and processes, though defined, require an experienced project manager honing these skills and the artist driving the successful project delivery. Additionally, a project engages a group of people together in achieving the objectives, so project managers understand key resources are people. The more they are valued, the project manager sees an increased level of respect and ensures effective project management throughout the life cycle of the project.

13.3 Processes in Traditional Project Management

The project management basic steps include initiating, planning, executing, monitoring & controlling, and closing. During the initiating stage, the project idea is thought about, and a decision is made as to whether to proceed with the project. A feasibility study is performed during this phase to determine the pros and cons of pursuing the project as a whole or in phases. For example, a feasibility study conducted to improve the design engineering process for a renewable energy project would begin with an assessment of the available wind or solar energy potential for a given geographic area, any land permitting constraints, cost constraints, and so on.

During the planning stage, the goals and requirements of the project are materialized with concrete plans for execution. The basic structure and the order of the project are developed using a project charter. In the case of a renewable energy project, this document would lay out goals on the tentative size of the system, project budget, timelines for design and construction, and so on.

During the executing stage, the goals and requirements are implemented by the project manager by conducting kickoff meetings and bringing together the project teams and key stakeholders. The work is assigned to the project teams by the project manager, and coordination-related items pertaining to scope are discussed and recorded for project tracking purposes. For example, in the renewable energy project, the kickoff meeting may comprise design engineering teams to get familiarized with the project's key objectives and milestones. And, thus start working on the project deliverables to meet the milestones.

During the monitoring and controlling stage, the project manager monitors the project's progress by conducting regular progress meetings. Any feedback required to make changes to the deliverables per the objectives is provided to keep the project deliverables quality controlled during the life cycle of the project. For example, a design document developed with calculations on solar energy output may be reviewed from the engineering and constructability aspects by the project manager and other quality control team members. And, thus eventually the final project documents are delivered to the client.

During the closing, during this stage the project is officially closed and lessons learnt are documented for future projects. The reason why this is a required step is to ensure the project was completed per the objectives laid out and that the stakeholders agree to the outcome and have no objections to the project deliverables. Moreover, successful projects are celebrated during the closing phase.

Project management is valuable during the development of power engineering and renewable energy projects that impact multiple stakeholders. Traditional project management steps have certain limitations but are highly used methods in the engineering and construction industry. So, within the scope of this book

other methods of project management such as Agile, Scrum, Lean, and Kanban were unexplored.

14. LIMITATIONS OF ELECTRIC VEHICLE CHARGING INFRASTRUCTURE AND PROSPECTS OF HIGHER OPERATING VOLTAGE AND POWER CAPACITIES

Abstract:

The purpose of this article is to evaluate the major limitations of the electric vehicle charging infrastructure, which will become useful for future improvements in this industry. Some major providers of electric vehicle charging stations have seen a drop in their performances resulting in their failure to develop a sustainable business around this sustainable practice of electrification. However, there are also major technical challenges with respect to the deployment of the chargers, starting from safe levels of operating voltage and capacity (kW) to allowing a wider range of ambient temperatures for operation. Past literature does indicate the necessity of operating the equipment within permissible temperature ranges, but there is less known literature to document how the higher voltage and capacity levels would impact the customer's safety. Since a higher kW capacity at higher voltage offers reduced charging session times. Reduced charging session time is attributed to better customer service.

14.1 Introduction

The swift growth in the electric vehicle industry is increasing the need for a fast and reliable charging infrastructure to sustain the transportation infrastructure. Electric motors and their operation in conjunction with batteries became a driving factor for scaling the business for electric vehicles. Although engineering standards and safe practices in the industry ensure publicly available electric vehicles and corresponding charging infrastructure are within permissible safety limits for operation, there is room for advancement by devising innovative solutions to improve the safety of equipment considered unsafe in the current context. For example, the users of residential homes are limited to a supply of (120/240) V power systems and commercial buildings with (277/480) V (Acharige, Haque, Arif, Hosseinzadeh, & Oo, 2023). Whereas higher voltage ranges at low and medium voltages are available to industrial customers. For example, many process industries own medium voltage substations and distribution to power heavy-duty process equipment. The major reasons for being considerate for operating voltages are to ensure the shock hazards are within permissible limits and to limit the current conduction by the human body during an electrical hazard.

The article is divided into sections mainly, Introduction: which talks about the background of electrical safety for electric vehicle charging stations (EVCS). Methodology: which talks about the major industry challenges with EVCS businesses and identifies current technical limitations. Furthermore, it provides a conceptual framework for required innovations in EVCS.

Results: The documents projected improved charging session times at given capacities. Conclusion: This concludes the article with major findings from the results.

14.2 Methodology

Some EVCS manufacturers, such as Tritium, faced major issues with their market expansion and successful delivery of products in the United States due to their inability to increase profits at scale and improve their reliability issues. Although per the available news, measures were taken to close its Australian factory and start production in the United States and obtain government support, the company still faced to successfully gain through its fully liquid-cooled fast-chargers as the second largest player in the EVCS industry (Ludlow, 2024). However, its acquisition by Exicom to solve the cost-cutting measures and increase profits promises commitment to the 2021 Bipartisan Infrastructure Law (John, 2024). Tables 14.1 – 14.2 illustrate some of the major challenges of electric vehicle charging stations per available literature.

Table 14.1. EVCS businesses limitations/ problems with solution

S. No.	Limitation/ Problems	Solution
1	Design Flaw	Improve Research & Development, and product innovation from customer feedback
2	Quality Control Problems	Improve product testing, and quality assurance and control measures
3	Supply Chain Problems	Improve supplier network
4	Manufacturing Process Problems	Improve processes to utilize economies of scale and scope
5	Lack of Government Support	Improve outreach to the Government
6	Lack of Sustainable Business Model between customers and company (Zheng, Keith, Wnag, Diao, & Zhao, 2024)	Eradicate product design flaws and improve customer satisfaction with quality products

Table 14.2. EVCS Technical Limitations with Solution

S. No.	Limitation/ Problems	Solution
1	Operating Voltage Range (between 480V to 120V)	Allowances up to 1000V
2	Operating Power Capacity Range (between 350kW to 7.5 kW)	Allowance up to 1000kW
3	Operating Temperature Range (60 K to 80 K)	Allowance up to 100K
4	Thermal Management Systems (Ali, 2023)	Allowance of advanced thermal management measures

14.3 Design Electric Vehicle Charging Station

Let us design a power distribution system for a single level 2 AC slow charger rated at 240V, a single phase at 19.2kW. Table 14.3 summarizes the key formula for obtaining the capacities of the over-current protection device and current-carrying conductors. Although detailed designs are governed by the existing codes and standards in the local jurisdiction Table 14.3 gives an engineering analysis of the power distribution system design. Based on the calculations for Table 14.3, the size of the conductors and overcurrent protection device must support 100A at 240V, Single-Phase and 115.38A at 208V and Three-Phase power supply. However, the capacity required to accommodate the charger to the service equipment is 100 A and 66.61A respectively. Similarly, this concept applies to a 480V, Three-phase DC fast charger rated at 150kW capacity.

14.4 Results

The current engineering standards have stringent measures to reduce electrical safety hazards while using electrical equipment per many OSHA guidelines and electrical engineering safety standards by NFPA. The major areas of both improved voltage and power capacities, as enlisted in Table 14.3, become an area of focus for EVCS manufacturing companies in improving their products. Fig. 14.1 shows a projected (theoretical) charging capacity vs charging session time for 20-80% State of Charge (SoC) levels for a 100kW battery pack.

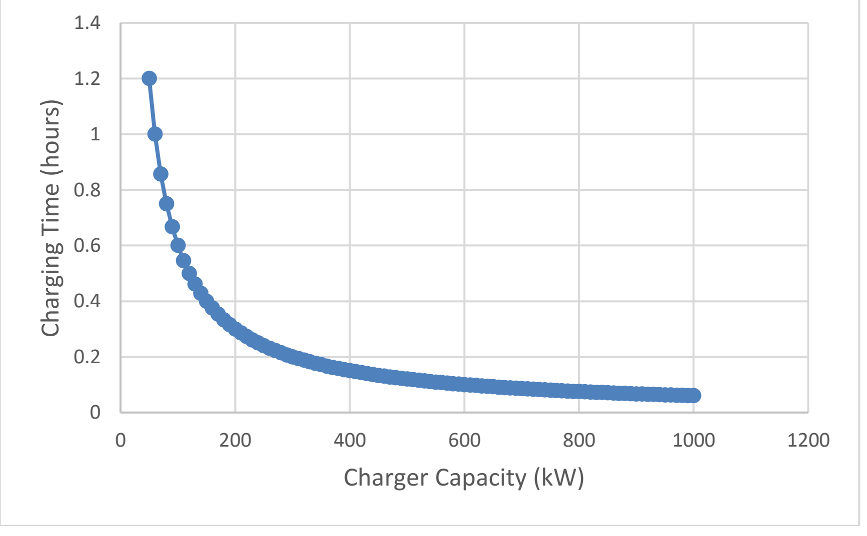

Fig. 14.1. Theoretical charging session time

Table 14.3. Conductor sizing with different volt

Element	120/240V, Single-Phase System (A)	208V, Three-phase System (A)
Conductor Sizing & Over Current Protection Device Sizing	$I = 1.25\frac{Total\ kW}{240V}$	$I = 1.25\frac{Total\ kW}{208V}$
Capacity Required for Service Equipment	$I = 1.25\frac{Total\ kW}{240V}$	$I = 1.25\frac{Total\ kW}{\sqrt{3}.208V}$

*Note: *1.25 times is the safety factor for continuous loads and may vary depending on the local codes and standards. Additionally, voltage levels may differ as well*

Table 14.4. Conductor sizing with different volt (480v)

Element	480V, Three-Phase System (A)
Conductor Sizing & Over Current Protection Device Sizing	$I = 1.25\frac{Total\ kW}{\sqrt{3}.480V}$
Capacity Required for Service Equipment	$I = 1.25\frac{Total\ kW}{\sqrt{3}.480V}$

*Note: *1.25 times is the safety factor for continuous loads and may vary depending on the local codes and standards. Additionally, voltage levels may differ as well*

14.5 Conclusion

The EVCS industry business challenges illustrated in Tables 14.1 – 14.2 were enlightening for EV enthusiasts. Nonetheless, the address of the technical constraints in improving the capacity ratings of the EVCSs becomes a key factor in the development of a safe and reliable infrastructure appealing to customers with reduced charging session times. Although the manufacturers of fast chargers have developed ultra-fast chargers at higher operating voltages and power capacities, many engineering standards and industry practices limit higher capacities. Thus, the development of electrical hazard-free equipment by limiting the shock hazards to customers from the EVCS becomes a key factor in the scalability of the power capacities.

15. COMPONENTS OF FULLY BATTERY ELECTRIC VEHICLE

The fully battery electric vehicle is characterized by the presence of an electric motor driven by a battery pack, each of varying types and chemistries, respectively. In general, the electric vehicle terminology represents any type of vehicle that supports an electric motor to drive the vehicle. The basic components of a fully battery electric vehicle are described in the following section.

15.1 Electric Motor

For traction, electric motors of varying types, such as induction, series reluctance, permanent magnet synchronous, brushless direct current, series, and shunt direct current motors, are used. The primary function of the motor is to

drive the wheels via a transmission system for speed controls. The speed controls are provided either by frequency or pole changing by use of microcontrollers operating to ensure the required speed vs torque controls per driver's command. Typically, the motors are rated at 30kW for low-performance city drive vehicles and 80kW or higher for high-speed applications. The size may also vary depending on the size of the vehicle. For example, a typical commute bus may have a 255kW motor operating with a battery pack of 315kWh to provide a driving range of 200 miles and longer.

15.2 Electric Battery

For traction, the battery pack comprised of high-energy density provides power for the traction electric motor. The batteries are rechargeable with capabilities in both charging and discharging. However, many researchers have presented concepts of battery replacement with non-rechargeable batteries. Additionally, researchers have modeled Lithium-ion batteries to accurately predict the current, voltage, and power performances (Theodore & Şahin, Modeling and simulation of a series and parallel battery pack model in MATLAB/Simulink, 2024). The battery pack power is rated within a typical range of 50-100kWh, where kWh is the kilo-watts of electrical energy consumed in one hour. Although, with medium and heavy-duty vehicles, this may range from 200kWh or higher.

15.3 Battery Management System

This is an onboard computer that monitors the charging and discharging cycles to ensure battery healthiness and safety of battery operation and alert drivers of the next charge.

15.4 Thermal Management System

This system ensures the electric motor, electronic controllers, power converters, and batteries are operating at a safe temperature range. This is either an air or liquid-cooled system.

15.5 Electronic Components

The power converters capable of converting AC to DC and DC to DC power, speed controllers, and safety devices comprise the major electronic components of an electric vehicle.

15.6 Mechanical Components

The mechanical components comprise a transmission system, wheels, axle, heating and cooling system, and all other body components.

15.7 Electric Vehicle Battery Safety

Lithium-ion batteries have characteristic curves for both charge and discharge cycles. Although with aging, the battery characteristic curves tend to alter, an improved efficiency is possible by improving the temperature of operation. Thus, an effective thermal management system comes into the picture wherein it can improve the battery performance with reduced temperature of operation. Engineering standards such as IEC 62133 establish the requirements of battery tests for safety and performance. However, battery-safe operations are significantly in the hands of safe operating temperature zones. When a battery equation is obtained for a typical electric vehicle (EV), the effects of temperature can easily be related to battery charge and discharge cycles. In manufacturing industries, the focus is on ensuring compliance with standards so that they pass and pose low to nil safety hazards. Improper design of batteries leads them to catch fire and cause explosions. For example, EVs from major car manufacturers have caught fire when occupied in parking garages close to residential apartment buildings.

Assessment of the temperature of operation of the EV batteries becomes crucial from a battery manufacturing and specifying perspective. The battery electrical model is represented by a series and parallel combination of resistors and capacitors; the charging follows a typical curve at a given temperature, and similarly, discharging follows a typical curve at a given temperature. However, in a steady state (such as parked condition), how the battery performs with temperature rise or drop both in performance and from a safety point is what is required based on incidences and published research. The limitations of the study may surround compliance pathways as stated in IEC standards and available information on EV fire incidences from published media news. Increased power output from li-ion batteries from the suitable temperature of operation requires an assessment from a safety standpoint as well. It may be seen low temperatures may improve the performance and vice versa but stresses EV batteries are exposed to depending on global temperatures are subject to study for car manufacturers when operating in different geographies. Integration of the Solar PV system with Li-ion batteries continues to be a topic of research and its application in sustainable agriculture with enhanced irrigation systems from their integration derives a positive environmental impact (Manfo, A Comprehensive Analysis of Material Revolution to Evolution in Lithium-ion Battery Technology, 2023; Manfo & Şahin, Development of an Automatic Photovoltaic Cell-Battery Powered Water Irrigation System Incorporated with Arduino Software for Agricultural Activities, 2024).

16. MODELING BATTERY CIRCUIT USING TRANSFER FUNCTION MODEL FROM EQUIVALENT CIRCUIT ELEMENTS

Abstract:

A battery circuit is characterized by the presence of a series of combinations of capacitors and resistances with the internal resistance of the battery connected

to a voltage source. None of the recent research provided simplistic modeling of the battery circuit using a transfer function methodology for predicting the voltage and current curves. The research paper formulates mathematical equations of the equivalent battery circuit using transfer function analysis. MATLAB simulation results validated the characteristics of the battery using the transfer function in the s-domain. The real-world application of this battery circuit in electric vehicle modeling has become a factor in this research and development project. The higher energy density of the Lithium-ion batteries modeled using the presented model simulates the state of charge (SoC) predictive curves.

16.1 Introduction

Renewable energy generation has increased the battery energy storage systems at utility-scale projects (Auch, Kuthada, Giese, & Wagner, 2023; Theodore, Structural, electrical, and electrochemical studies of the olivine LiMPO4 (M=Fe, Co, Cr, Mn, V) as cathode materials for lithium-ion rechargeable batteries based on the intercalation principle, 2023; Badi, et al., 2022). Lithium-ion (Li-ion) batteries became a key driver force in revolutionizing the way electronic devices are used for many purposes and then assisting the transition to electric vehicles and renewable energy storage with provisions of high energy density, both scalable and safe. Energy densities increased to significant levels with li-ion chemistry which has not only resulted in reduced costs per kW but also increased safety per kW. Extended life from the battery management systems further saves the cost by increasing the useful life of the battery for both new and used cases. For example, researchers have established the useful life of the batteries after their end of use from regular use of electric vehicles. The major ingredients within the cell allow versatile operation in recharge and charge cycles. Electrodes, both cathode and anode made from graphite or lithium cobalt oxide allow the ionic medium to smoothly move ions between through the porous separator. The direction of the flow of the electrons or ions is dependent on the charge or the discharge cycle. Typically, in a charge cycle, the external power source displaces the electrons to its charged orientation whereas a discharge cycle pushes electrons in the external circuit. The process of power use from li-ion batteries from small electronic devices has scaled to large applications such as electric vehicles (Badi et al., 2022).

The traction motors are already electric in nature but they are governed by drawing power from overhead catenary or third rail. For electric vehicles, a catenary or third rail system is subject to feasibility analysis as the magnitude and scale of the infrastructure required becomes a limitation for a catenary system for electric vehicles. However, many tram services for roadway transportation draw the benefits from overhead catenary systems without battery storage on board. Energy storage systems require reliable battery packs to provide power to the grid from the renewables which have intermittent power generation, this balances the generation profile by a steady flow of electricity from the renewables to the power grid. For example, many regions experience load shedding due to heavy reliance on renewable energy when there is a lack of minimum cut-in speed for the wind to run the wind turbines efficiently. In

providing sustainable transportation solutions, major automobile manufacturing companies have delved into exploring weight reduction of batteries per kW to increase the kWh/ mile consumption of the vehicles. Some manufacturers have developed strategic business relationships with major battery manufacturers across the globe to reduce costs and improve more energy-efficient product profiles. Collaborative efforts come from joint relationships between the automobile, battery, and charging infrastructure manufacturers. Electric vehicle chargers must be capable of supporting a wide range of EVs without compromising the quality of charge and similarly, EVs must be capable of supporting the types of charging available without creating any additional burden on exploring different charger types. However, the SAE standards govern the types of chargers namely levels 1, 2, and 3 with charging connectors with SAE J1772, NACS J3400, CCS, and CHADeMo (Tekin & Karamangil, 2024). With a growing market in electric vehicles, the standards may change, and thus, respective changes to the way the automobile industry shifts in electric vehicles could be impacted.

The battery level is indicated by its state of charge (SOC). Often, this parameter is analogous to the fuel level inside a conventional internal combustion engine (ICE) automobile. Smartphone electronics allow monitoring of the battery SOC and smartly disengaging the applications consuming more power during low battery levels. A similar concept is applied to Li-ion batteries in EV applications through a battery management system. The SOC levels are often determinant of the drive miles remaining during its application in EV. It also becomes a key factor during shipments. For example, there are recommended levels of SOC% (Radaš, Pilat, Gnjatovic, Šunde, & Ban, 2022) with varying modes of transport (road, air, or waterways). Additionally, to improve the battery life many recommended practices ensure discharge until 20% and recharge until 80% SOC levels. But accuracy of determination of battery SOC level remains a subject for research wherein optimization of the useful energy from the battery is a prime concern.

Simulation of the battery using modeling software such as MATLAB is an essential tool for both researchers and industry professionals. The Simulink feature allows the block modeling of the mathematical models from equivalent circuits of the battery. Additionally, transfer function models developed for the battery equivalent circuits allow obtaining the characteristics for the open circuit voltage (OCV) and SOC levels. Typically, a battery equivalent circuit comprises of resisters and capacitors connected in series or parallel combination. For example, a set of resisters and capacitors in parallel is connected to another set of similar elements in series with the internal resistance of the battery. The individual circuit elements, such as resistors and capacitors, can be modeled in the Simulink, or a transfer function block may be modeled to produce the battery characteristic curves. The methods section provides a transfer function approach to modeling the battery and obtaining its characteristic curves.

Safety concerns regarding the batteries remain a topic of discussion, but hazards from an electric vehicle battery, when compared to the operation of ICE vehicles, are lower per many published research (Barai, Uddin, Widanage, McGordon, & Jennings, 2018). However, safety at rapid charging of the battery at higher voltage and current levels becomes a topic of concern both from standards development and personnel safety standpoint. Battery recycling adds environmental hazards, but from the life cycle assessment (LCA) of ICE vs EVs, EVs lead the way. Containing electrical fires vs petroleum products fires are different from fire containment measures. For example, dry chemical power type extinguishers or foam-based hydrant systems are specific for petroleum fires, whereas, for electrical fires, in addition to these mitigation techniques, carbon monoxide extinguishers often become a recommended option.

16.2 Matlab Simulation Model

The transfer function is a Laplace transform of the output to the input. Using a transfer function model of a system the output can be obtained with given input. For example, a system of wheel movement balanced by the load can be transformed into a transfer function with the input being weight and the output is the rotations per minute (rpm) of the tire. Similarly, for a li-ion battery, the transfer function available from past literature is shown in equation (1) (HUANG, Wang, & FENG, 2020). This model represents the dynamics of the battery and is applicable in a wide range of real-world uses for battery state estimation and controls.

$$G(s) = \frac{V(s)}{U(s)} = \frac{y_2 s^2 + y_1 s^1 + y_0}{x_2 s^2 + x_1 s^1 + x_0} \tag{1}$$

where G(s) is the battery transfer function, V(s) is the Laplace transform of the output and U(s) Laplace transform of the input.

The current input and the output voltages are related using the transfer function. The major benefits of using the transfer function for battery modeling include changing the order, identification of the parameters, SOC estimation, verifying the frequency response, and dynamic response. The transfer function approach offers advantages in computational efficiency and real-time applicability, making it suitable for battery management systems and control algorithms in various applications, from consumer electronics to electric vehicles. Using equation (1) the transfer function block was drawn in MATLAB Simulink with assumed values of each of the coefficients for both the output and the input.

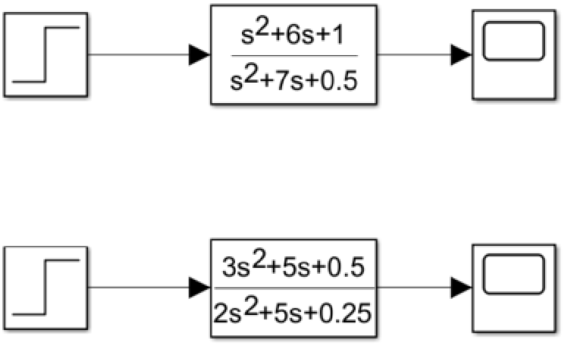

Fig. 16.1. MATLAB model

16.3 Analyzed Results

The results are shown in Figs. 16.1 – 16.2 for varying coefficients. Clearly, the characteristics indicate the steady output after a given increment of the input variable.

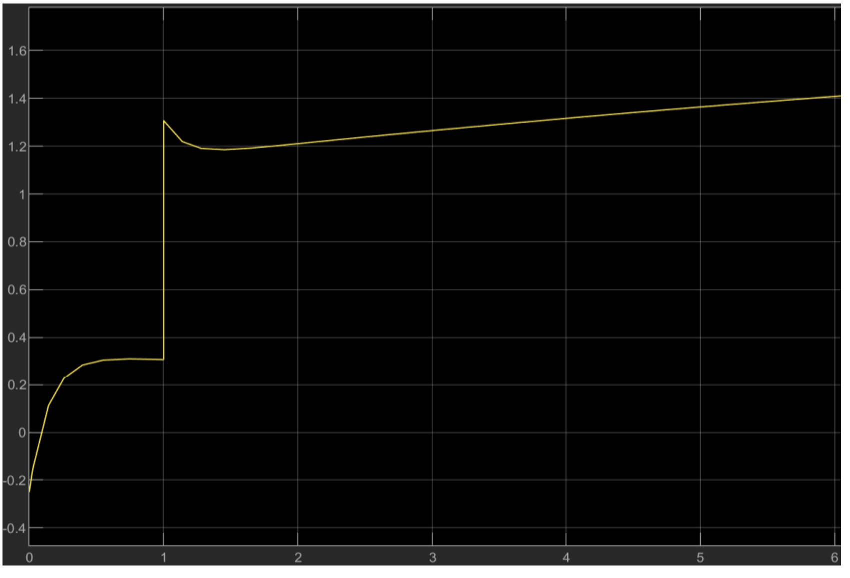

Fig. 16.2. Input vs Output characteristics

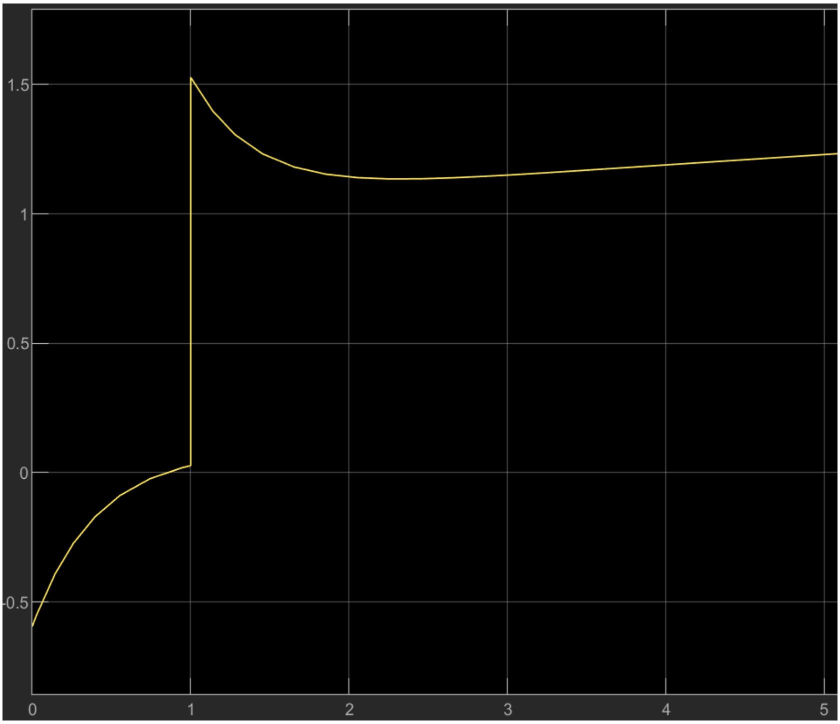

Fig. 16.3. Input vs Output characteristics

16.4 Conclusion and Discussion

The modeling battery circuits performed using transfer function models derived from equivalent circuit elements such as resistance, capacitance, and voltage source element allows for predicting lithium-ion battery behavior and obtaining the battery characteristic curves. The gap between the electrochemical model and the electrical model is bridged using mathematical modelling using various concepts such as s-domain, frequency domain, z transform, and so on. A greater level of accuracy is obtained when a transfer function model is implemented using the Laplace domain (s- domain) which not only captures the transient response but also the steady-state response allowing dynamic responses of the battery. The key elements incorporated include: open-circuit voltage (OCV), internal resistance (IR), and resistance-capacitance (RC) networks representing various time-constant phenomena within the li-ion battery. The transfer function model can be altered using the changes to the order, which enhances the balance of complexity and accuracy, with third-order models often providing a good compromise. This approach presented here enables researchers, engineers, and battery experts to simulate battery performance and its characteristic curves under varying conditions of the internal battery chemistry,

estimate the state of charge, and thus develop efficient battery management systems. This facilitates the model to be applicable in many practical applications of electric vehicles and renewable energy storage. Furthermore, the safety improvements from the battery modelling allow the required standards review to make the safety of the vehicle a more prominent feature for customer use. The transfer function modelling is simplistic in nature but advanced statistical tools and techniques may be devised to prepare more accurate results for battery management.

The future scope of battery modelling revolves around the changing battery chemistries for the application in electric vehicles and other renewable energy storage applications. The aim is to increase the energy density at reduced costs which makes the modelling multifaceted when comparing the equivalent circuit elements. The models may get more sophisticated and techniques as machine learning and artificial intelligence-trained models are developed to make more educated decisions on battery management. The battery chemistry evolution in upcoming years will result in the transfer function models becoming more sophisticated by the incorporation of machine learning techniques with capabilities to capture complex nonlinear behaviors, safe operating conditions, and long-term degradation effects. Researchers, engineers, and battery experts are focused on the development of models that adapt to battery real-time conditions, such as climate conditions, temperature, plugged-in or pulled-off, battery age, and so on. Integration with artificial intelligence algorithms could enable predictive maintenance and more efficient battery management systems, particularly for large-scale applications like electric vehicle fleets and grid energy storage. The ongoing innovations and rapid transitioning to electric vehicles with faster charging and higher energy density batteries will likely drive further refinement of these models to capture rapid dynamic responses accurately.

17. WIND ENERGY

17.1 Wind Turbine

The aerodynamic force for the rotor blades drawn from the wind is utilized to generate electricity from synchronous generators from wind turbines. Given the high wind speeds available in coastal regions, many off-shore wind turbines are commercially scalable for increasing the renewable energy penetration into the power grid. Some of the challenging aspects of wind turbines include installation with structurally stable poles, and their prolonged maintenance free from any defects.

17.2 Betz Law

Betz law defines the limit of the useful power from wind's kinetic energy to 59.3% for wind turbines. This lays a theoretical maximum efficiency of the wind turbine.

17.3 Wind Speed Map India

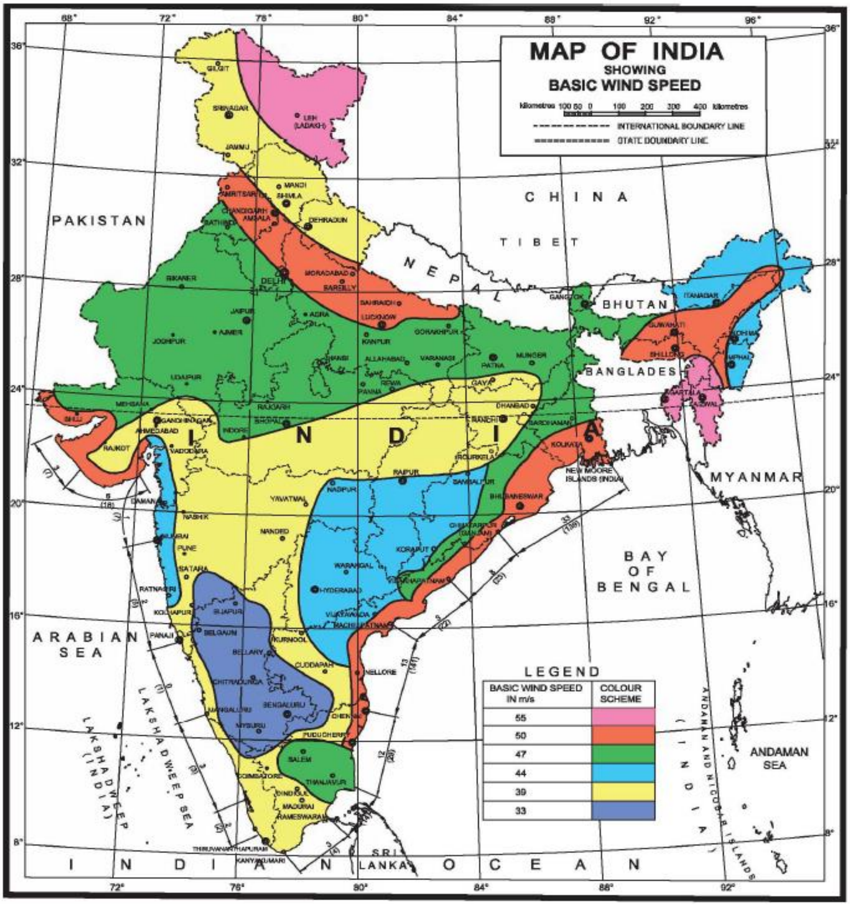

Fig. 17.1. Wind speed map of India
(Source: GHTC) (GHTC, 2016)

17.4 Conceptual Design

The conceptual design for a wind turbine system for a location in Hassan, Karnataka, is based on the availability of wind speeds supporting the commercialization of wind energy systems. Several sites in close proximity to the industrial areas become tentative sites for such installations. Due to limitations on using any of the specific sites in this area, a typical layout of five turbines rated at 20kW (nominal capacity) was proposed with a total installed potential of 100kW within the area of 18.3 acres of land. Using the Aeolos-H 20kW model, the available annual energy output is 23.08kWh at 5m/s speed. Considering only 9 months of available speed of 5m/s the average output with five turbines is 86.5MWh.

17.5 Return on Investment Analysis

Assumptions for this analysis were the cost were taken from 2011 records and respective analysis were done based on interest rates and taxes during the given timeframe. The annual energy savings from the generation of electricity is summarized in Table 17.1. Since the renewable energy projects are exempt from taxes Table 17.2 shows the annual tax savings for a ten-year period. Similarly, the expenses are shown in Table 17.3 for equipment and Table 17.4 for the interest paid on the borrowings of the principal money for the wind turbine installation. Finally, Table 17.5 summarizes a flat returns on investment percentage based on the savings vs expenses comparison.

Table 17.1. Electricity generation

S. No.	Year	Tariff for 1kWh (Rs)	Annual Energy Savings (Rs)
1	1	7.59	654,637.50
2	2	8.12	700,462.13
3	3	8.69	749,494.47
4	4	9.30	801,959.09
5	5	9.95	858,096.22
6	6	10.65	918,162.96
7	7	11.39	982,434.37
8	8	12.19	1,051,204.77
9	9	13.04	1,124,789.11
10	10	13.95	1,203,524.34
11	11	14.93	1,287,771.05
12	12	15.98	1,377,915.02
13	13	17.09	1,474,369.07
14	14	18.29	1,577,574.91
15	15	19.57	1,688,005.15
16	16	20.94	1,806,165.51
17	17	22.41	1,932,597.10
18	18	23.98	2,067,878.89
19	19	25.65	2,212,630.42
20	20	27.45	2,367,514.54
		Total Bill =	26,837,186.60

Table 17.2. Tax savings on renewable energy

S. No.	Year	Principle (Rs)	Tax Savings @ 30.9% (Rs)
1	1	23,390,640.00	7,227,707.76
2	2	4,678,128.00	1,445,541.55
3	3	935,625.60	289,108.31
4	4	187,125.12	57,821.66
5	5	37,425.02	11,564.33
6	6	7,485.00	2,312.87
7	7	1,497.00	462.57
8	8	299.40	92.51
9	9	59.88	18.50
10	10	11.98	3.70
11	11	2.40	0.74
12	12	0.48	0.15
		Total =	**9,034,634.66**

Table 17.3. Equipment cost

S. No.	Equipment	Amount (Rs)
1	Wind Energy Generator	1,415,610.00
2	Tower	935,550.00
4	Grid Controller	239,400.00
5	Inverter	750,960.00
6	Installation	1,336,608.00
	Total (1 unit) =	**4,678,128.00**
	Total (5 units) =	**23,390,640.00**

Table 17.4. Interest paid on borrowings

S. No.	Year	Principle	Instalment	Interest paid
1	1	23390640.00	2339064	2,105,157.60
2	2	21051576	2339064	1,894,641.84
3	3	18712512	2339064	1,684,126.08
4	4	16373448	2339064	1,473,610.32
5	5	14034384	2339064	1,263,094.56
6	6	11695320	2339064	1,052,578.80
7	7	9356256	2339064	842,063.04
8	8	7017192	2339064	631,547.28
9	9	4678128	2339064	421,031.52
10	10	2339064	2339064	210,515.76
			Total =	**11,578,366.80**

Table 17.5. Returns

Investment (Rs)	34,969,006.80
Savings (Rs)	35,871,821.27
Returns (Rs)	902,814.47
% Return per annum	0.13

17.6 Conclusion

A model presented for the wind turbine installation at Hassan, Karnataka is feasible both respect to available wind energy in the area and returns calculation. Betz's law limits the output of the wind turbine to 100% based on the physics and dynamics involved with the wind energy. The Aeolos-H model was used to determine a typical output of the turbine at 5m/s speed for a nine-month duration. Although the wind potential is available in the area with positive returns, the selection of the site is dependent on several aspects of land acquisition policies in place by the local government.

18. SOLAR ENERGY

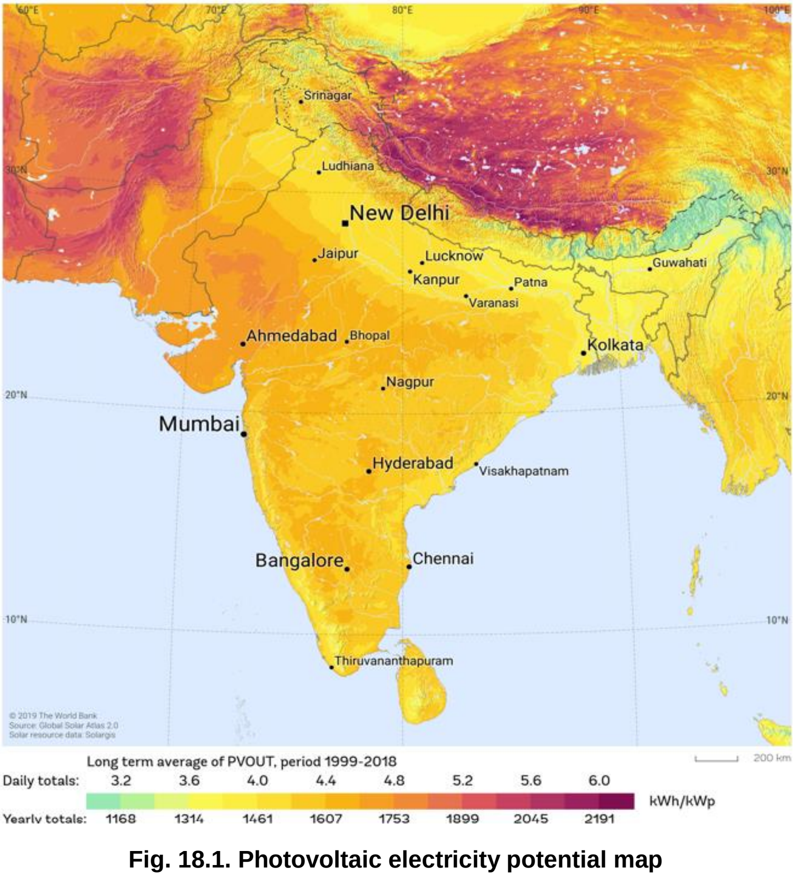

Fig. 18.1. Photovoltaic electricity potential map
(Source: SolarGIS) (Solar GIS, 2019)

Solar energy serves as a resource for photosynthesis for plants and keeps the global temperature warm enough to support life. The artificial use of solar energy

to produce electricity is possible from solar photovoltaic panels. The use of solar energy to produce electricity and reducing reliance on conventional energy resources not only reduces the dependence on fossil fuels but also reduces the associated greenhouse gas (GHG) emissions. Ground-mount solar farms and roof-top solar are two different concepts available for residential, commercial, and utility-scale applications. Fig. 18.1 shows the photovoltaic electricity potential map for India per SolarGIS.

Major components of a solar photovoltaic system comprise the PV module, inverter, battery storage system, electrical power distribution system, and safety equipment. The determination of the size of the system typically starts with accessing the total demand load for the system along with future additions. There are several methods to calculate the load for both normal and peak-time operations. Based on the same the type of PV module is selected, and the number of modules is chosen based on available space. Accordingly, inverters are sized to accommodate inrush or surge currents. Typically, a 25-20% safety factor is considered before sizing the inverter to mitigate nuisance tripping from the inrush currents in the system. Additionally, battery bank sizes are governed by the total required number of hours of operation of the system at a given load in ampere-hours (Ah). These calculations are recommended to be performed by using some software tools such as the NREL System Advisory Model (SAM). In Figs. 18.2-18.3, the results from the NREL SAM for calculating the annual energy output from a Solar PV system of 500kW in Jaipur, Rajasthan, are presented using the PV Watts method. The total energy generated is around 752 MWh.

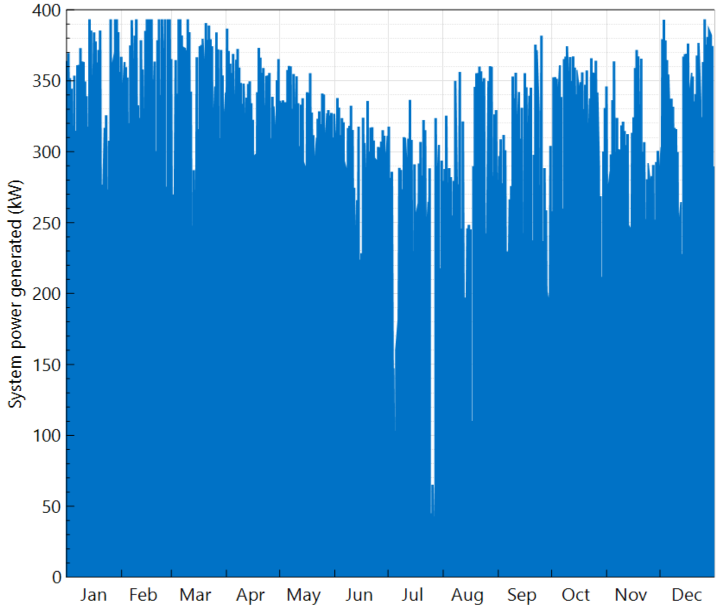

Fig. 18.2. Power generated (kW)

18.1 Photoelectric Effect

The photoelectric effect is defined as the release of electrons from the striking of light onto the material. An open circuit potential difference is created across the material. When connected to a load across the terminals of a semiconductor material of n-p-n or p-n-p composition, this open circuit potential difference results in the movement of electrons in the external circuit (current). The types of solar photovoltaic systems include thin film, monocrystalline, polycrystalline, and so on. Depending on the cost and the efficiency required for the system the type of module is chosen from the mentioned types.

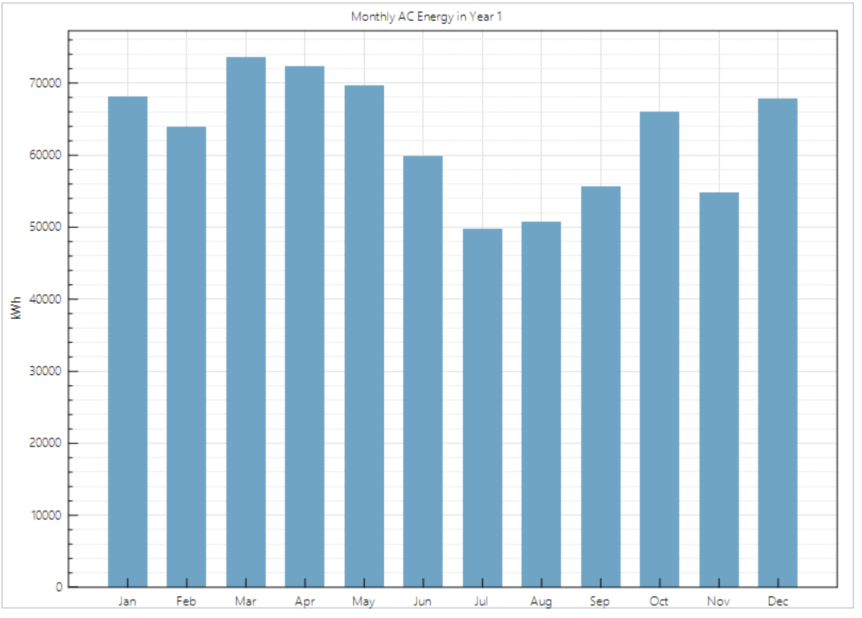

Fig. 18.3. Power Generation (kWh)

18.2 Trends in Solar Energy

Many government initiatives in incentivizing the development of residential, commercial, and utility-scale projects have resulted in private companies rapidly transforming the renewable energy generation profile in India to up to 500 GW by 2030. Many factors are contributing towards large-scale adoption as enumerated below:

- Cost reduction from the grown-up market and globalization of the products
- Improved technology in increased kW at the given cost of material
- Additional Government Policies and Incentives
- Improved clean energy awareness

- Mandates per the local energy and building standards

18.3 Intermittency of Generation

The power intermittency in generation during low irradiance values at given time of the day to nil at night impacts the power grid. The demand curves show peak usage during the day and evening hours, but during the nighttime, there is a significant reduction in demand. Although this is a positive indication when using solar energy, an alternative strategy in improving the generation profile during the night from renewables is required. One such solution is to add a battery energy storage system, which may discharge into the grid the stored power from solar generation during the day. The introduction of li-ion chemistry in battery technology has allowed the practicality of this concept in the real world. Many utility companies have grid-scale battery energy storage systems (BESS).

18.4 Conclusion

Solar energy from its residential, commercial, and utility-scale represents a powerful tool in the transition toward a sustainable and clean energy future. Its rapid growth, increased awareness, government incentives, and improved generation profile from battery energy storage systems are increasing its large-scale adoption in many markets around the world. Designing a safe system without compromising the personnel safety is of prime importance when developing systems with large battery energy storage systems. Conceptually, it is possible to add large battery energy storage to balance the generation profiles when solar generation is low or nil. However, there are still limitations with cost implications for these large sized storage systems and their useful life.

19. HYDROGEN STORAGE AND SOLAR PV SYSTEM

19.1 Introduction

The project is aimed at obtaining hydrogen from electrolyser using solar energy along with its proper storage for application in fuel cell-based electric vehicles. A single diode model for PV cells is studied and its equations are used in MATLAB programming. PV cell is modelled considering both shunt and series resistance. In order to obtain the characteristics of the photovoltaic system, current equations of PV systems were used. Using the maximum power point on I-V characteristics, the corresponding current value as output is fed to the electrolyser. The hydrogen generated is directly proportional to the input electrolyser current [reference]. The current vs hydrogen-generated characteristics are in line with the equations used. Initially, the temperature and irradiance are set at a constant value of 25 C and 1000 W/m^2 respectively. However, during analysis, the irradiance values varied based on the intensity of sunlight at various locations- Phoenix, Wichita, Boston, and Houghton.

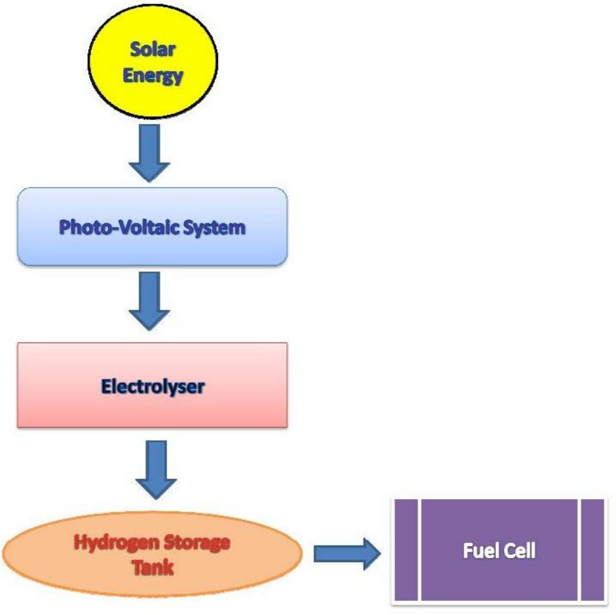

Fig. 19.1. Schematic diagram of hydrogen generation

Hydrogen being a clean source of energy is best suited for application in a fuel cell. Thus, for efficient use of hydrogen gives rise to the need for an efficient storage system. However, there are several challenges to storage technologies pertaining to hydrogen in large amounts due to safety issues. Hence, in this project, Pressurized hydrogen storage is proposed.

This approach of using MATLAB programming and Simulink is simple modeling of PV and electrolyser system along with storage system, which helps to study the system characteristics. And, also helps to find an optimum quantity of hydrogen through an electrolyser which in turn runs a fuel cell. Hence, the system can be reconfigured to meet the fuel cell demand for hydrogen. The schematic diagram of hydrogen generation using solar energy is shown in Fig. 19.1.

19.2 Solar PV Principle of Operation

Light has both particle and wave nature. Considering the particle nature light travels in packets termed photons- the driving source of the photo-voltaic system. A solar cell is basically a solid-state device (p-n junction) that converts solar radiation (photons) into electricity. The entire process is governed by the photovoltaic effect along with the generation of current. In this process, two dissimilar materials connected to each other closely, when struck by solar radiation produce the potential difference. In particular, p and n-type

semiconductors are these materials. The electrons are excited at one material, upon striking of sunlight which in turn crosses the junction and flows into the load circuit. The schematic diagram of Solar Cell is shown in Fig. 19.2.

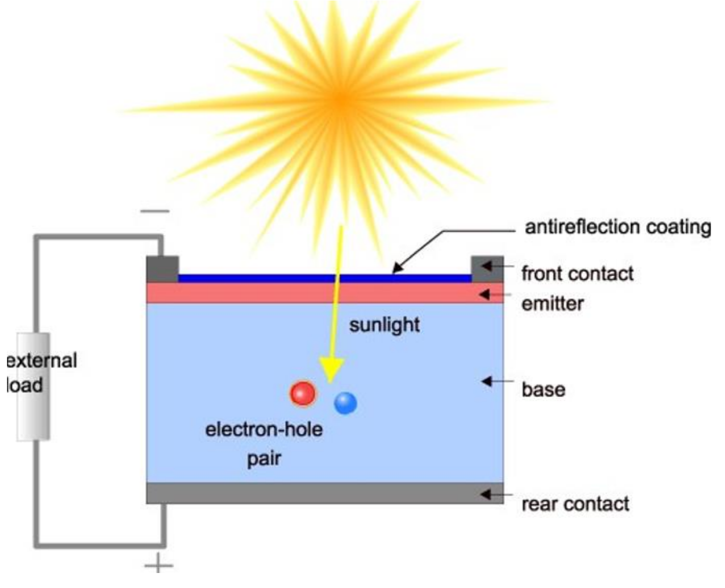

Fig. 19.2. Cross-section view of PV cell
(Source: pveducation.org) (PV Education, 2013)

19.3 Electrical Model of PV Cell

The equivalent circuit of a PV cell can be represented by Fig. 19.3 and a more practical model considering shunt and series resistances is shown in Fig. 19.4.

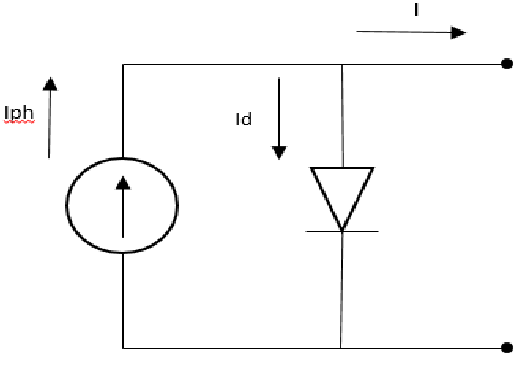

Fig. 19.3. Single diode model

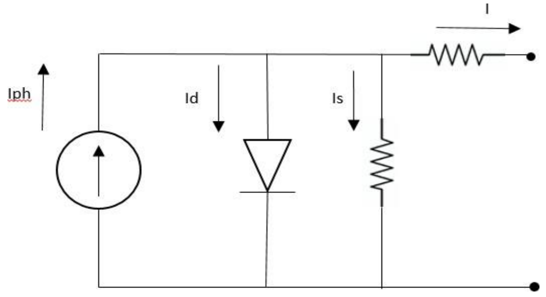

Fig. 19.4. Single Diode Model with Shunt (R_p) and Series (R_s) resistances

For the circuit in Fig. 19.4. The total current through PV cell is given by:

$$I = I_{ph} - I_d - I_{ps}$$

I_{ph} = *light generated current in cell*
I_d = *diode current*
I_p = *current leakage in the shunt resistance*

Light generated current is given by:

$$I_{ph} = \frac{G}{G_n}[I_{ph,ref} + \mu_{sc}.(T - T_n)]$$

G = *irradiance*
G_n = *irradiance at standard condions* (STC) = 1000 W/m^2
$I_{ph,ref}$ = *photocurrent*
μ_{sc} = *coefficient temperature of short circuit current*

Reverse saturation current in given by:

$$I_0 = I_{0,ref}\left(\frac{T}{T_{c,ref}}\right)^3 . e^{\left[\left(\frac{qE_G}{A.K}\right)\left(\frac{1}{T_{c,ref}} - \frac{1}{T_c}\right)\right]}$$

$$I_{0,ref} = \frac{I_{sc,ref}}{e^{\left(\frac{V_{oc,ref}}{V_{Tn}}\right)} - 1}$$

Diode current is given by:

$$I_d = I_0\left[e^{\left(\frac{V - IR_S}{aV_T}\right)} - 1\right]$$

$$V_T = \frac{k.N_s.T}{q}$$

I_0 = reverse saturation or leakage current of the diode
V_T = thermal voltage
a = diode ideality factor
V = voltage imposed on diode
k = Boltzman constant
N_s = number of cells in series
q = charge of electron
T = actual cell temperature

Current leakage in shunt resistance is given by:

$$I_p = \frac{V + IR_s}{R_p}$$

R_s = series resistance
R_p = shunt resistance

The equations for PV system can be used to determine the output voltage and current through an array and this output is used as an input for electrolyser model. A detailed MATLAB code with initialized values of required parameters is shown in flowing section.

19.4 Electrolyser

A non-spontaneous reaction driven by DC current for separation of elements is called Electrolysis. An equipment used for the process of electrolysis is called electrolyser, which contains an electrolyte, two electrodes, and DC electrical supply.

Electrolyte: An ion conducting material with free ions in abundance, the reactions are not spontaneous.

Electrode: Electric conductors present between the electrolyte and external DC supply.

DC Supply: A reaction driving energy that helps in separation of materials at the junction of electrolyte and electrodes.

19.5 Modeling of Electrolyser

The modeling of electrolyser can be divided into two parts as:

a. Electrical Part
b. Electrochemical and Thermodynamic Part

Electrical Part:

Depending upon the parameters taken for the electrolyser model the operating voltage as a whole of the activation, ohmic overpotentials, Nernst potential can be expressed as:

$$E_{cell} = E_{rev} + \left[(r_1 + r_2 T) * \frac{I}{A}\right] + [s_1 + s_2 T + s_3 T^2] * \log\left[\left(t_1 + \frac{t_2}{T} + \frac{t_3}{T^2}\right) * \frac{I}{A} + 1\right]$$

Elecrolyser voltage is:

$$E_{electro} = \eta_{cell} * E_{cell}$$

Electrochemical and Thermodynamic Part:

According to faraday's laws, the hydrogen production rate depends on the electrolyser current. Molar flow rate is given by:

$$H_2 = \frac{\eta I}{2F} \eta_F$$

$$O_2 = \frac{\eta_{cell} I}{4F} \eta_F$$

$$H_2O = 1.25 \frac{\eta I}{2F} \eta_F$$

Where η_F, is the Faraday Efficiency or Current Efficiency:

$$\eta_F = a_1 * \exp\left[\left((a_2 + a_3 * T) * \frac{A}{I}\right) + \left((a_4 + a_5 * T) * \frac{A^2}{I^2}\right)\right]$$

Table 19.1. The parameters of the electrolyser model are as given in table below

r_1	7.3e-5	Ωm^2	r_2	-1.1e-7	$\Omega m^2/C$
s_1	1.6e-1	V	s_2	1.38e-3	V/C
s_3	-1.6e-5	V/C^2	t_1	1.60e-2	m^2/A
t_2	-1.3	m^2C/A	t_3	412e2	m^2C^2/A
A	0.25	m^2	a_1	99.5%	
a_2	-9.58	m^2/A	a_3	-0.056	$m^2/A/C$
a_4	1502.7	m^4/A	a_5	-70.8	$M^4/A/C$
N_{el}	21		T_{el}	25	C

r_1, r_2 - Parameters for ohmic resistance of electrolyte
s_1, s_2, s_3 - Parameters for over voltages across electrodes t_1, t_2, t_3 - Parameters for over voltages across electrodes
A - area of electrode
I - electrolyser stack current
a_1, a_2, a_3, a_4, a_5 - Parameters for current efficiency

$$\text{Volume Flow rate} = \text{Molar flow rate} * \left(\left(\frac{\text{mol}}{\text{s}}\right) * \left(\frac{3600\text{s}}{1\text{hr}}\right) * \left(\frac{0.022414\text{m}^2}{\text{mol}}\right)\right)$$

19.6 Simulink Modeling of Electrolyser

A simulink modeling approach utilizes an electrolyser. Faraday efficiency with some approximations can be obtained as shown in these equations:

$$\eta_F = 96.5 * e^{\left(\frac{0.09}{i_e} - \frac{75.5}{i_e{}^2}\right)}$$

The output hydrogen in moles/sec is given:

$$\eta_{H_2} = \frac{\eta_F n_c i_e}{2F}$$

n_c = No. of photovoltaic cells
i_e = electrolyser current
F = Faraday's constant

Assuming time of operation as 9 hours the output hydrogen in kg is obtained in this Simulink diagram shown in Fig. 19.5.

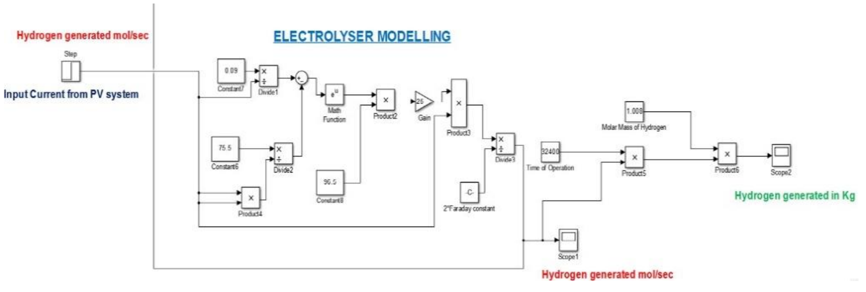

Fig. 19.5. Simulink model of electrolyser

19.7 Hydrogen Storage

The generalized equation for the hydrogen storage tank is as follows:

P_b: Pressure of the tank in N/m^2 (pascal)
P_{bi}: Initial pressure of the tank in N/m^2 (pascal)
Z: Compressibility factor as a function of pressure.
N_{H2}: Hydrogen moles per second sent to the storage tank in kmol/s
R: Universal gas constant in j/ (kmol K)
T_b: Operating temperature in Kelvin (K)

M_{H2}: Molar mass of hydrogen in kg/kmol
V_b: Volume of the tank in m^3

19.8 Simulink Modeling of Storage System

The storage dynamics can be modelled using equations involving initial pressure values.

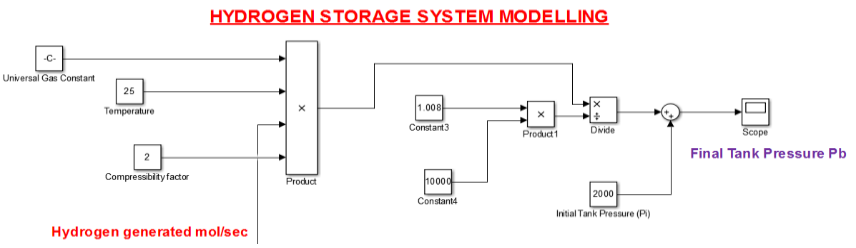

Fig. 19.6. Simulink model of hydrogen storage system

19.9 Electrolyser and Hydrogen Storage System

The integrated model for both electrolyser and storage is shown in Fig. 19.7.

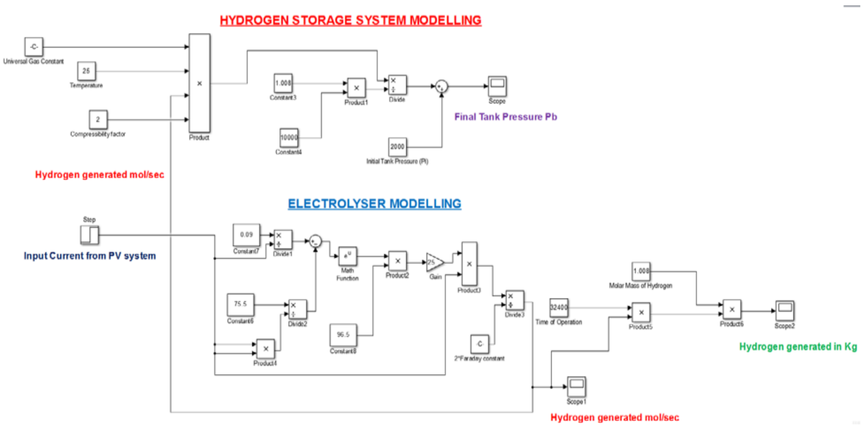

Fig. 19.7. Simulink model of the electrolyser and hydrogen storage system PV Cell and electrolyser characteristics

Using the MATLAB code V-I characteristics were obtained as shown in this section Fig. 19.8.

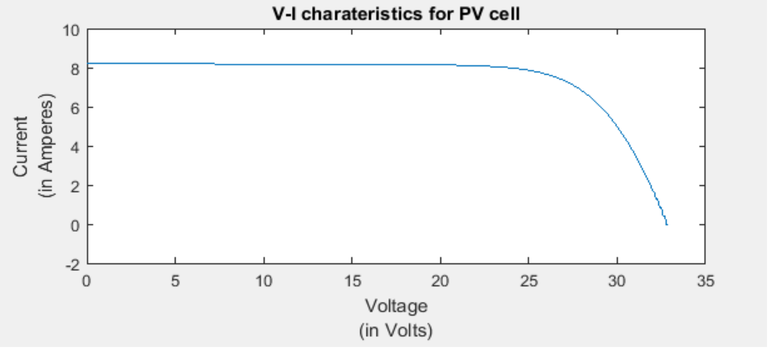

Fig. 19.8. V-I Characteristics of PV cell

Electrolyser current vs hydrogen output is obtained as shown in Fig. 19.9.

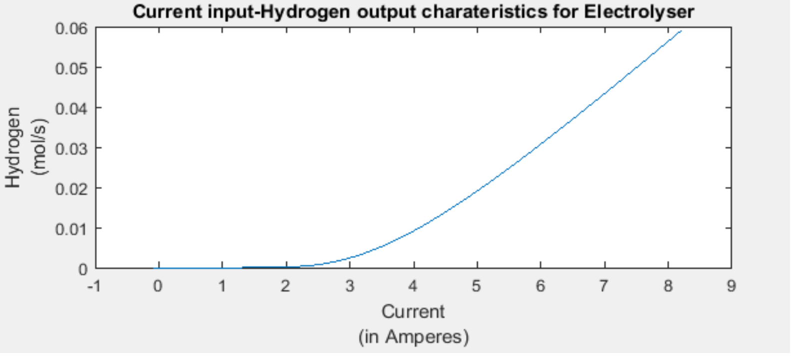

Fig. 19.9. Current input vs hydrogen output characteristics for electrolyser

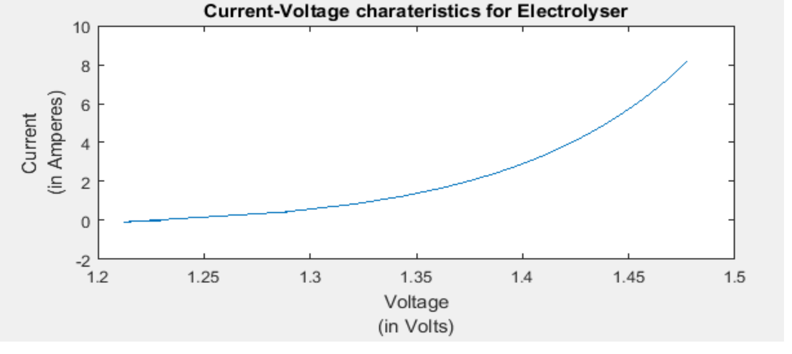

Fig. 19.10. Current vs voltage characteristics of electrolyser

The operation at Maximum power condition yields hydrogen output as 0.0268 mol/s.

19.10 Hydrogen Consumption Analysis

For carrying out feasibility studies of the designed/modelled system real-time values for irradiance are obtained from the NREL website for four cities namely Phoenix, Wichita, Boston and Houghton as shown in Table 19.2.

Also, a Hyundai Tucson fuel cell-based vehicle is used in the study to determine the quantity of hydrogen that can be fueled in vehicles of such type throughout the year.

Compare Fuel Cell Vehicles

Fuel cell vehicles (FCVs) are now for sale or lease in the United States although availability is limited to areas with an adequate number of hydrogen refueling stations. Fuel economy estimates and other information are provided below.

	2016 Hyundai Tucson Fuel Cell	2016 Toyota Mirai
		
	Fuel Economy and Related Estimates	
Fuel Economy (mi/kg)	**50** comb, 49 city, 51 hwy	**66** comb, 66 city, 66 hwy
Range (miles)	265	312
Annual Fuel Cost *	$1,7(0	$1,250
	Vehicle Characteristics	
Vehicle Class	Small SUV	Subcompact Car
Motor	AC Induction (100kW)	
Battery	180 V Lithium Ion	245 V NiMH
Availability	Select dealers in California (lease only)	Select dealers in California initially (sale or lease)

* Annual fuel cost calculated assuming a hydrogen cost of $5.55/kg, 15,000 annual miles of travel, and 55% city and 45% highway driving.

Fig. 19.11. Fuel cell vehicles comparison
(Source: Fuel Economy) (Fuel Economy, 2016)

As per the studies shown in Table 19.3 and Fig. 19.13, it is observed that for Phoenix, the number of vehicles (fuel tank capacity 5 kg) fueled during June month is around 350 per month which corresponds to the $ 90,000 gasoline fuel price.

Table 19.2. Irradiance values of various locations in the United States

Month	Average kWh/sqm/day				Average kW/sqm (Solar Irradiance)			
	Phoenix	Wichita	Boston	Houghton	Phoenix	Wichita	Boston	Houghton
January	4.7	3.7	2.7	1.8	522	411	300	200
February	6.2	4.6	3.8	3.1	689	511	422	344
March	7.8	5.8	5.1	4.9	867	644	567	544
April	9.9	7.2	6.2	6.3	1100	800	689	700
May	11	7.9	7.1	7.4	1222	878	789	822
June	11.4	8.8	7.7	8.1	1267	978	856	900
July	10	9.1	7.7	8.1	1111	1011	856	900
August	9.6	8.2	7	6.9	1067	911	778	767
September	8.6	6.7	5.7	5	956	744	633	556
October	7.1	5.4	4.2	3.2	789	600	467	356
November	5.3	3.8	2.6	1.7	589	422	289	189
December	4.4	3.2	2.2	1.4	489	356	244	156

Table 19.3. Hydrogen generation and vehicle-fueled

Month	**Hydrogen generation in kg (with 9 hrs operation)**				**No. of vehicles fueled per month**			
	Phoenix	**Wichita**	**Boston**	**Houghton**	**Phoenix**	**Wichita**	**Boston**	**Houghton**
January	13	0.5	0.0	0.0	3	0	0	0
February	135	10.2	0.7	0.0	27	2	0	0
March	475	85.5	29.3	19.6	95	17	6	4
April	1165	319.0	134.5	149.7	233	64	27	30
May	1589	503.6	298.2	369.5	318	101	60	74
June	1749	773.9	477.9	562.0	350	155	96	112
July	1202	875.9	477.9	562.0	240	175	96	112
August	1054	592.1	276.1	254.9	211	118	55	51
September	708	219.6	74.8	24.2	142	44	15	5
October	298	47.8	3.4	0.0	60	10	1	0
November	41	0.8	0.0	0.0	8	0	0	0
December	6	0.0	0.0	0.0	1	0	0	0
Total:	**8434**	**3429**	**1773**	**1942**	1687	686	355	388

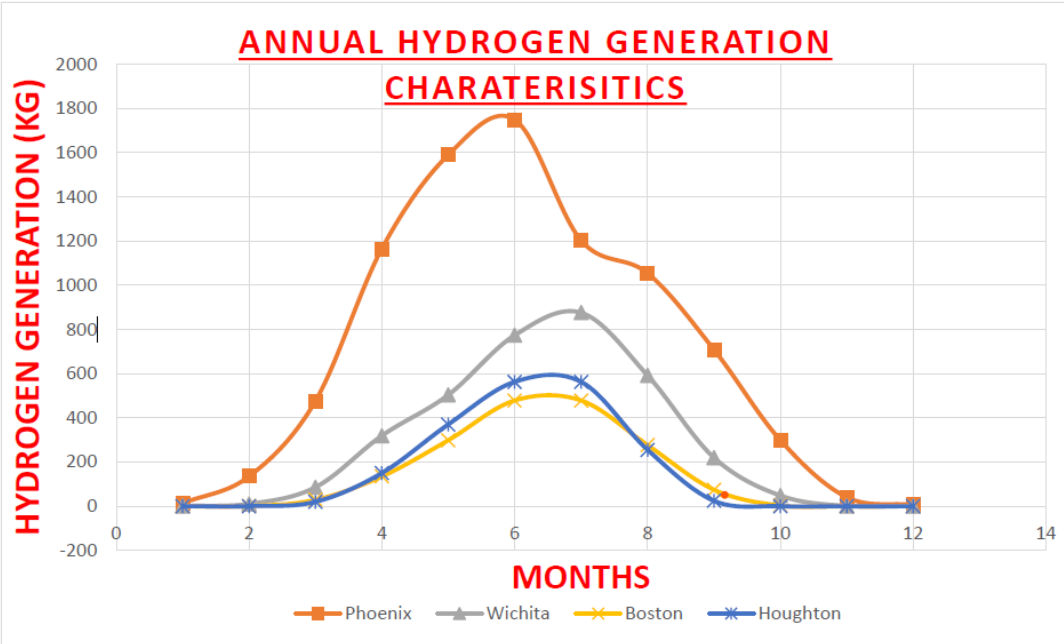

Fig. 19.12. Annual hydrogen generation characteristics

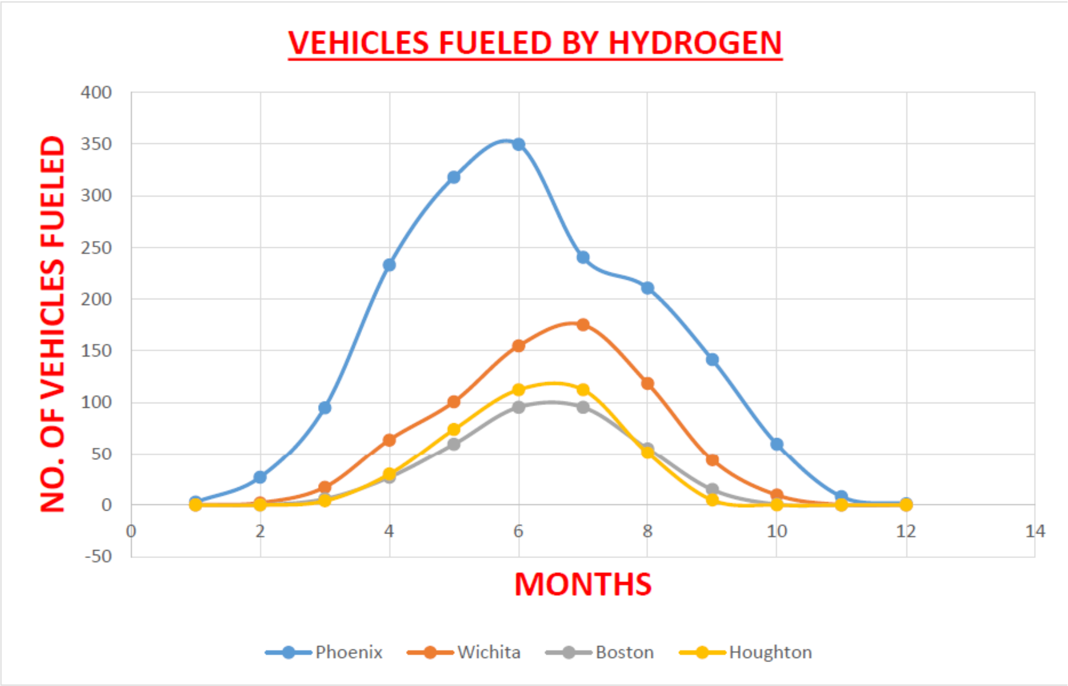

Fig. 19.13. Vehicles-fueled by hydrogen

19.11 Conclusion

By using MATLAB programming and Simulink tools, a simple model for obtaining hydrogen from an electrolyser using a PV system and its storage has been simulated. The average irradiance values are obtained from the NREL website for four cities—Boston, Houghton, Phoenix, and Wichita. A comparative study shows the feasibility of the installation of a fuel cell-based system for this location. The study shows Phoenix located in the eastern part of America could be the most feasible location for setting up a fuel cell system. Additionally, locations with medium solar irradiance values like Wichita have also the potential for hydrogen generation plants. Since the mileage of certain fuel cell-based electric vehicles is in the range of 50 miles/kg, it is possible to have large-scale usage of fuel cell-based electric vehicles by installing hydrogen generation plants at probable locations determined by the study presented.

20. OVERALL SUMMARY AND CONCLUSION

Opportunity cost determines the feasibility of pursuing a project by giving up on the other option available. During power generation choice between fossil-fueled and renewable energy, the business evaluates the opportunity cost when pursuing renewable energy as a preferred option. Additionally, customers evaluate the benefits of decarbonization from the electric vehicles of battery or fuel cell types. Less benefits and more expenses are forgone for good in most cases. Lessons learned from the major sportswear, automobile, petroleum, and retail fashion products provide greater accountability of marginal cost and marginal revenue during the pricing of the products which has a direct application in the renewable energy industry. Although it is recommended to increase the value of the products, the increasing value increases the price and thus a price-sensitive audience may walk away. Many firms deploy market monopoly as a strength in overcoming the market forces. This market monopoly is driven by a pioneering technology of super quality limited to a given manufacturer. Similarly, many products in electric vehicles and charging stations from leading companies such as Tesla present a strategized approach to beating the market forces of their products monopolistic in nature.

From the entry of new market competitors often a gaming strategy is utilized to ensure the company withstands the entry of new products. A simple example of a comparison of new automobile products for a Bajaj vs Suzuki dealership was compared to present the use case of the gaming strategy and Nash equilibrium. Whereas the value creation remains the top choice of businesses, decision-making during the uncertainty of success with new product launches was studied. Standard costing advantages outweigh the disadvantages and thus as presented in this book becomes a solution for the renewable energy industry. Bridging the gap between engineering management and design, an overview of project management processes for the traditional waterfall model was enumerated with the major steps starting from initiating, planning, executing, monitoring & controlling, to closing.

A major limitation of the evolving electric vehicle charging is limited charging session time. To improve the charging session times, it is recommended to increase the voltage and power capacity of the equipment to achieve theoretically achievable charging session times of 1-3 minutes. However, this results in the evaluation of the safety of users and personnel from an engineering safety standards standpoint. State of charge (SOC) estimation is a highly venerated topic in the electric vehicles industry as it allows for improving the vehicle safety and healthiness of the battery. Similarly, major renewable energy integration projects require battery energy storage systems to even the generation profile during the night time (or low solar irradiance at a given time of the day). Transfer function modeling in MATLAB was used to prepare the characteristics of battery curves to assist with SOC determination.

Wind and Solar energy are major sources of renewable energy available in major parts of the world. In India, from the wind speed and solar irradiance maps, it is evident that renewable energy has the potential to reduce dependence on fossil fuel-based generation. A conceptual design of a wind power project with an installed capacity of 100kW at Hassan, Karnataka became promising when the generation resulted in 86.5kW by factoring in the intermittent wind speeds throughout the year. The Betz law limits the potential of usable kinetic energy from the wind, but from available wind turbine products, the return on investment is positive. Similarly, a solar power project with an installed capacity of 500kW at Jaipur was modeled to project the generation of up to 752 MWh. This validates the government initiatives in increasing the renewable energy generation to 500 GW by 2030.

Hydrogen is an energy source for driving fuel-based electric vehicles, which is an explored research topic. The feasibility study, which involved the combined operation of an electrolyser and storage, was modeled using MATLAB. There were positive indications with the installation of hydrogen generation from electrolyser and its storage around the United States. Existing fuel cell-based electric cars can derive hydrogen from a combined system that harnesses solar energy and uses it to run an electrolyzer. The safety of the installation of a hydrogen storage system becomes a topic of further discussion.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that No generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

COMPETING INTERESTS

Author has declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Peer-Review History:
This book was reviewed by following the Advanced Open Peer Review policy. This book was thoroughly checked to prevent plagiarism. As per editorial policy, a minimum of two peer-reviewers reviewed the manuscript. After review and revision of the manuscript, the Book Editor approved the manuscript for final publication. Peer review comments, comments of the editor(s), etc. are available here: https://peerreviewarchive.com/review-history/4547

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